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July 1996

Report 1

Identification of Sediment Types Offshore of the Broadkill Beach, Delaware, Area

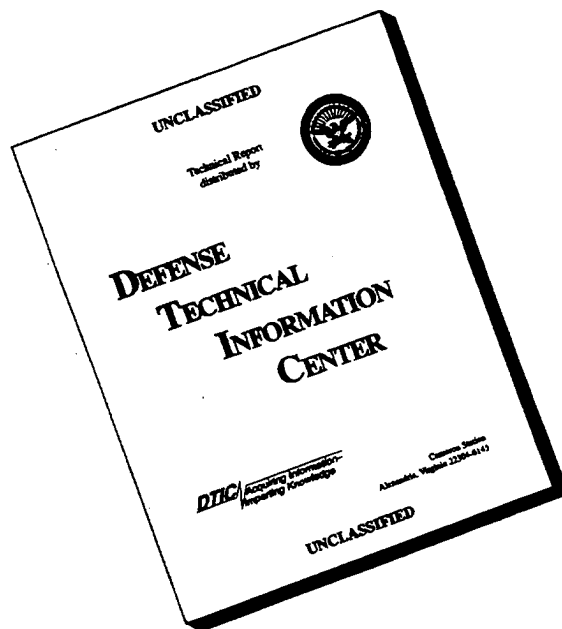
by Donald K. Stauble, Richard G. McGee

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Sediment Characterization and Beachfill Borrow Area Assessment of the Delaware Bay Study

Report 1 Identification of Sediment Types Offshore of Broadkill Beach, Delaware, Area

by Donald K. Stauble, Richard G. McGee

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Report 1 of a series

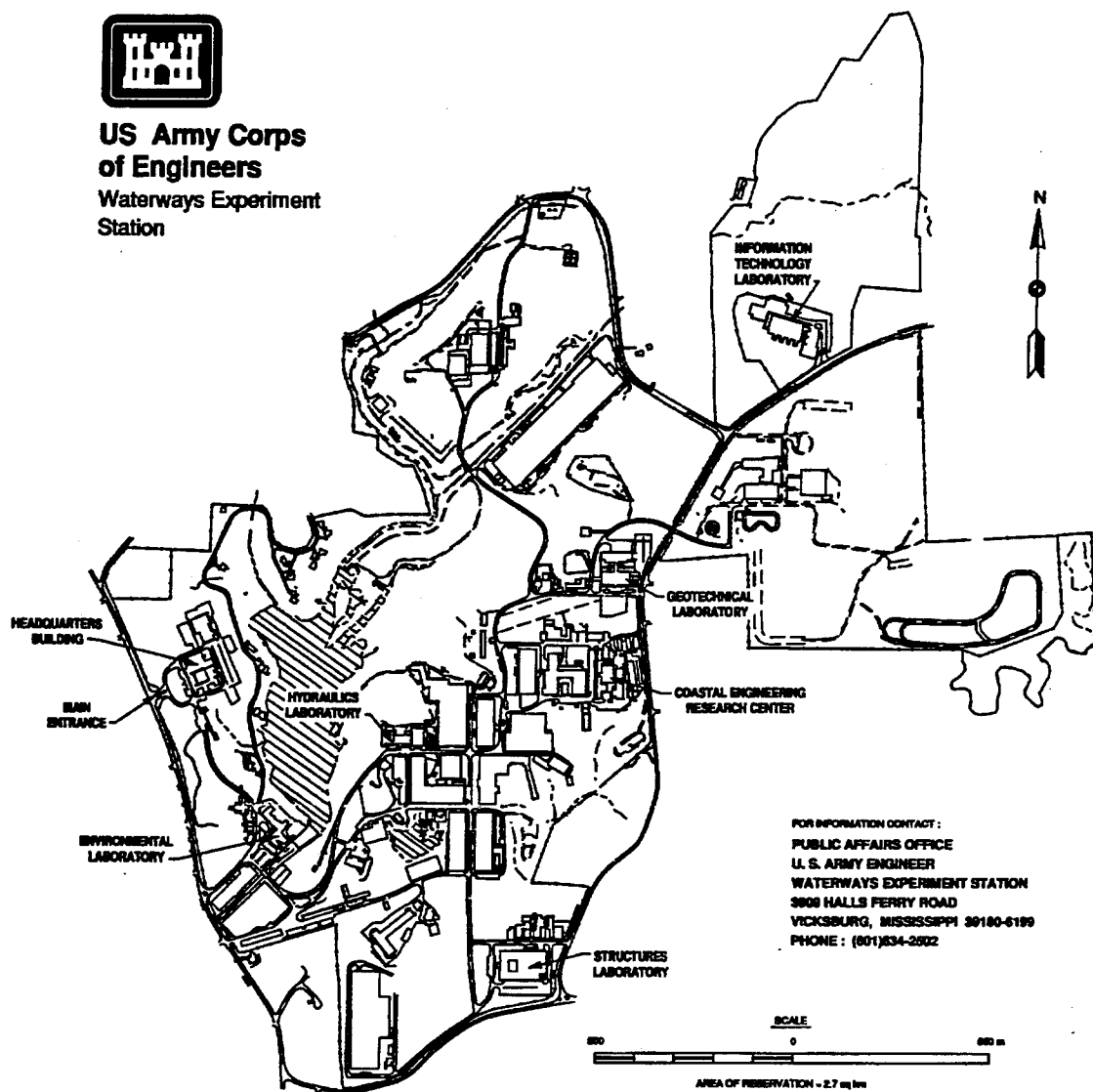
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Report 1 of a series.

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Preface

The work described herein was authorized as part of a Feasibility Report for the Delaware Bay Study, U.S. Army Engineer District, Philadelphia (NAP). The study was conducted by the U.S. Army Engineer Waterways Experiment Station's (WES's) Coastal Engineering Research Center (CERC) and Hydraulics Laboratory (HL). Technical Monitors at Headquarters, U.S. Army Corps of Engineers, were Messrs. John H. Lockhart, Jr., and Barry W. Holliday.

This report was prepared by Dr. Donald K. Stauble, Team Leader, Coastal Geology Unit, Coastal Structures and Evaluation Branch (CSEB), Engineering Development Division (EDD), CERC, and Mr Richard G. McGee, HL. Dr. Stauble was under the administrative supervision of Ms. Joan Pope, Chief, CSEB, Mr. Thomas Richardson, Chief, EDD, Mr Charles C. Calhoun, Jr., Assistant Director, and Dr. James R. Houston, Director, CERC. Mr. McGee was under the administrative supervision of Dr. Bobby J. Brown, Chief, Hydraulics Analysis Branch, Mr. Richard A. Sager, Assistant Director and then Acting Director, and Mr. Frank Hermann, Director, HL.

Work on this project was a cooperative effort between personnel of CERC, HL, and the WES Geotechnical Laboratory (GL). Seismic field data collection was done aboard the R/V Waterways Explorer (WES). Data collection was assisted by Messrs. Rodney Leist and Thomas S. Harmon, GL, Mr. Sam Varnell, HL, and Mr. David Caulfield, President, Caulfield Engineering Group, Oyama, British Columbia, Canada. Assistance in data reduction was provided by Ms. Claire Livingston (CERC, HL, and GL), and Ms. Darla McVan, HL. Mr. Brian Williams, HL, provided graphics support. Mr. Brian Murtaugh, Geotechnical Branch, NAP, provided the core logs and gradation curve data and acted as project monitor.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

| Multiply | By | To Obtain |
|------------------------------|-----------|---------------------------|
| feet | 0.3048 | meters |
| inches | 2.54 | centimeters |
| miles (U.S. nautical) | 1.852 | kilometers |
| pounds (mass) per cubic foot | 16.01846 | kilograms per cubic meter |

1 Introduction

In response to a request from the Philadelphia District (NAP) for assistance in identification of beachfill borrow areas offshore of the Delaware and New Jersey coasts within the Delaware Bay as part of a Feasibility Report for the Delaware Bay Study, the Coastal Engineering Research Center (CERC) in conjunction with the Hydraulics Laboratory (HL) at the U.S. Army Engineer Waterways Experiment Station (WES) is submitting Report 1 on the identification of sediment types offshore of the Broadkill Beach, DE, area.

Eroding areas of the bay shoreline have resulted in a need to investigate the shallow offshore areas of the bay adjacent to both the Delaware and New Jersey coasts for use as a borrow area for beachfill material. The area is relatively unexplored from a geotechnical standpoint and this investigation will provide acoustical subbottom profiling, vibracore locations, and interpretation of the sediment substrate of the study area. Figure 1 shows the extent of the seismic track lines and location of the sediment cores for the entire study area. The study will be subdivided into several reports on sections of the coast. Field work was conducted to provide seismic tracks of the study area. Existing data were reviewed concurrently to incorporate these data into the study. Vibracore locations were chosen based on the seismic data collected for this study and the existing data. The vibracore collection was done by the District, and provided to WES. Seismic and sedimentological data from these cores were interpreted, and this report characterizes the sediment of the Broadkill Beach portion of the Delaware Bay study and suggests suitable borrow areas for beachfill use.

Modern sedimentary deposits in Delaware Bay are controlled by past geologic processes. Lower Delaware Bay was thought to be a dendritic drainage pattern of gravely and muddy sands during the late Wisconsinan low stand of the sea around 15,000 to 12,000 years ago (Knebel et al. 1988). As sea level rose, the estuary became flooded as the bayside shoreline retreated northwest along the pre-transgression topography. A detailed history of the evolution of the bay shoreline on the Delaware side of the bay is presented in Fletcher et al. (1990). The sediment and bathymetry off Broadkill Beach are a result of this transgression of sea level into the drowned river valley. Coarse-grained sediments were originally deposited in the river beds. Rising

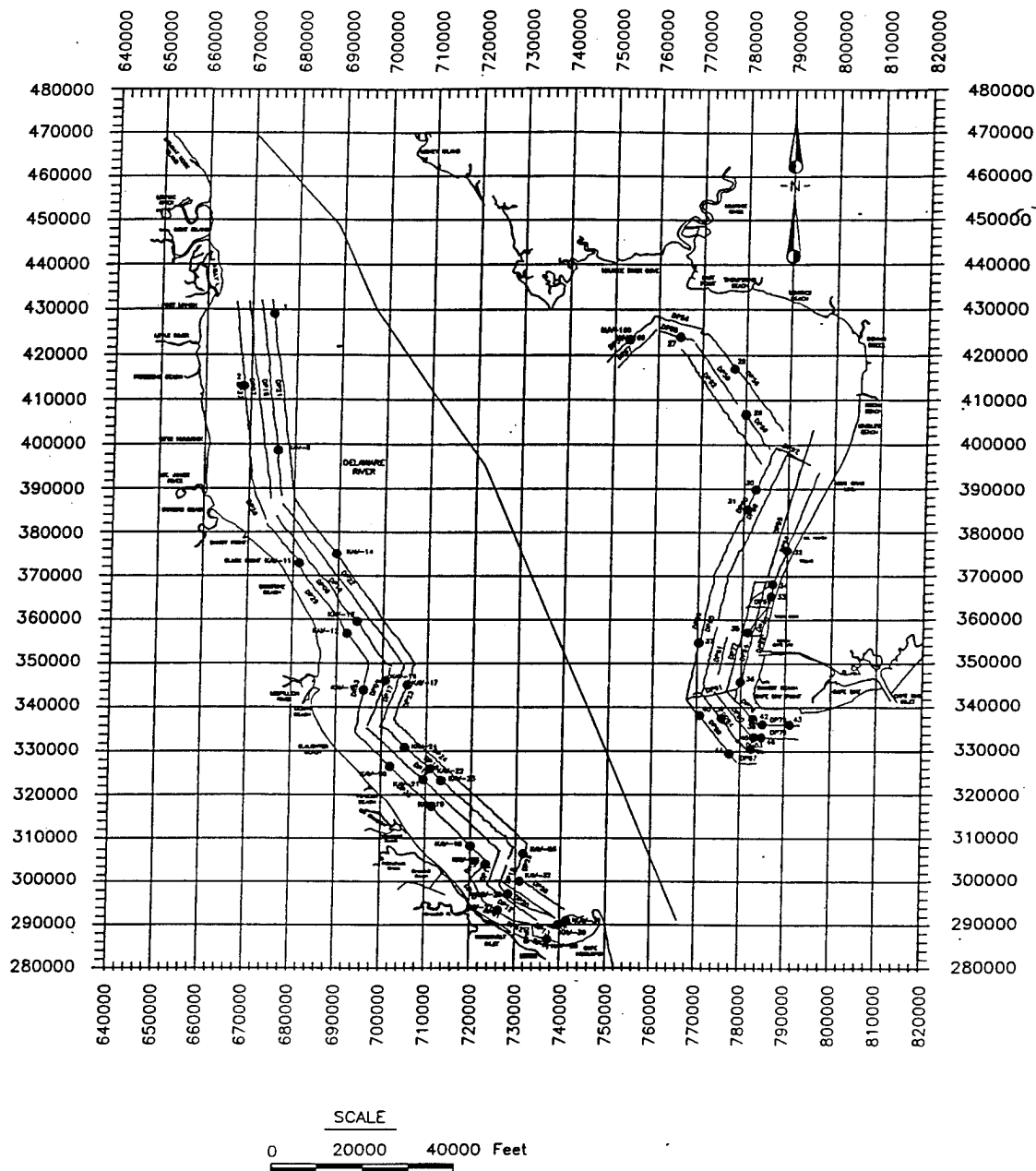


Figure 1. Location map of seismic track lines and cores collected along the Delaware and New Jersey shore of Delaware Bay¹

A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page vi.

sea level flooded these river valleys and fine silts and clays were deposited as the turbidity maximum migrated up the estuary. As the estuary grew, narrow barrier and headland beaches composed of fine to coarse sands were formed from wave and tidal action. Tidal marshes composed of silts were formed behind these barrier islands in the tributary river beds. In the present-day open estuary, sediment scour, reworking, and transport have become the dominant processes. Delaware Bay is a well-mixed estuary from Port Mahon to the bay mouth at Cape Henlopen.

2 Approach

Field work included planning, testing, and collection of new acoustic subbottom profile data along the Delaware and New Jersey shore adjacent areas (5-20 ft depths). The area between Port Mahon and Lewes, DE, was studied from approximately 1 to 3 miles offshore. The area approximately 1 to 3 miles offshore between the Maurice River mouth and Cape May Point was studied on the New Jersey side of the Bay. This field work was conducted on both the Delaware and New Jersey sides of the Delaware Bay in conjunction with field work on the Delaware River Main Channel Preconstruction and Engineering Design Study during the summer of 1993. The R.V. Waterways Explorer was outfitted with a fathometer, side scan sonar, 3.5-kHZ subbottom profiles, and a 600- to 900-Hz bubble pulser. A differential global positioning system (DGPS) was used to provide accurate positioning of the seismic lines. Details of the acoustic calibration are presented in the Delaware Ship Channel report by McGee (in preparation).

An analysis of core locations was provided to NAP at the completion of the field work to allow for a contract for vibracoring to be done in 1994. Sediment core logs and sediment grain-size analysis was performed by the South Atlantic Division Laboratory in February 1995. Analysis of the sediment characteristics and borrow area identification was done after receipt of the vibracore data from NAP in April 1995. The data analysis has been divided into two separate subsections that separates the analysis of the Delaware and New Jersey sides of the Bay at the request of the District. Similar analysis is being performed on both data sets and the data has been presented to the District in GIS-compatible format.

A review of existing sets of subbottom and core data was combined with the new field data collected to assess the bathymetry, stratigraphic sequences and sediment composition of the upper 20 ft of sediment along the Delaware and New Jersey shore adjacent areas of Delaware Bay. This report will focus on the southern Delaware Bay shore area between the coast and 3 miles offshore, from an area just south of the Mispillion River to Cape Henlopen. This includes the area offshore of Lewes and Broadkill Beach.

After the field work was completed a review the seismic data and assessment of the best locations to take cores to identify the sediment

characteristics and ground truth the seismic signature. Details of the analysis procedure are located in McGee et al. (1995).

3 Analysis

Identification of Possible Beach Fill Borrow Areas and Sand Substrate Identification

The purpose is to assist NAP with techniques and evaluation of the suitability of borrow areas for possible beach fill projects adjacent to the Delaware and New Jersey bay shoreline. Sediment data typing, grain size analysis interpretation and suggestion of borrow areas is provided to assist the State of Delaware in a proposed beach fill project along Broadkill Beach. Broadkill Beach is a small community located on the bay shoreline, 5 miles north of the mouth. A map has been generated and originally sent to the district by INTERNET as requested that shows the possible bottom types that can be used to select areas for possible sand sources for beach nourishment (Figure 2). This map of the surface sediment types was constructed from analysis of the seismic data and the surface sediment data from the cores. The use of core information has allowed a better refinement of the seismic data. The map outlines the best areas for possible sand.

Additional information, taken as part of a State of Delaware study of the nearshore area off Broadkill Beach, DE. was supplied by the State of Delaware. Two technical reports by Wethe et al. (1982) and Wethe (1984) indicate that there may be possible sand in the nearshore vicinity of Broadkill Beach. This area was inshore of our seismic study. A copy of the pertinent core locations and possible sand sources from these reports are found in Figure 3. Several former borrow areas used in 1961, 1973, 1975, 1976, and 1981 are shown in the nearshore region (around 1,000 ft from shore).

Former pre-transgressive river valleys appear to trend offshore in a southeast direction from the three present day rivers in the area (Maley 1981). Sand size material was identified in shoals between these former valleys (Figure 4). Cross-sections from Maley (1981) in the inshore area indicate that the sand shoals are over lagoonal mud deposits, particularly in the ancient valleys (Figure 5). The present data agrees with the Delaware reports. The interpretation of the surface acoustic impedance and sediment data shows that sand areas appear to trend in a NW-SE direction from the Delaware shoreline

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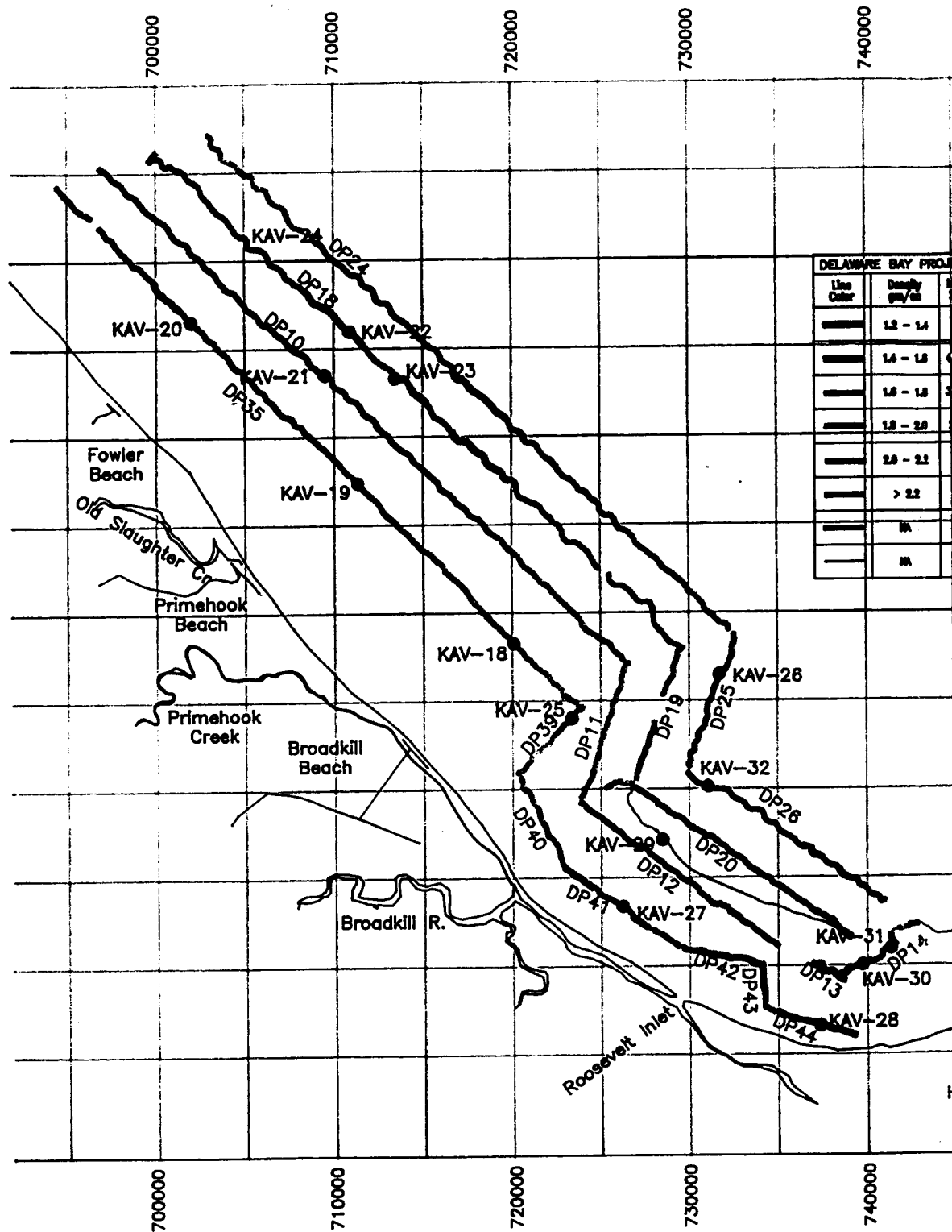
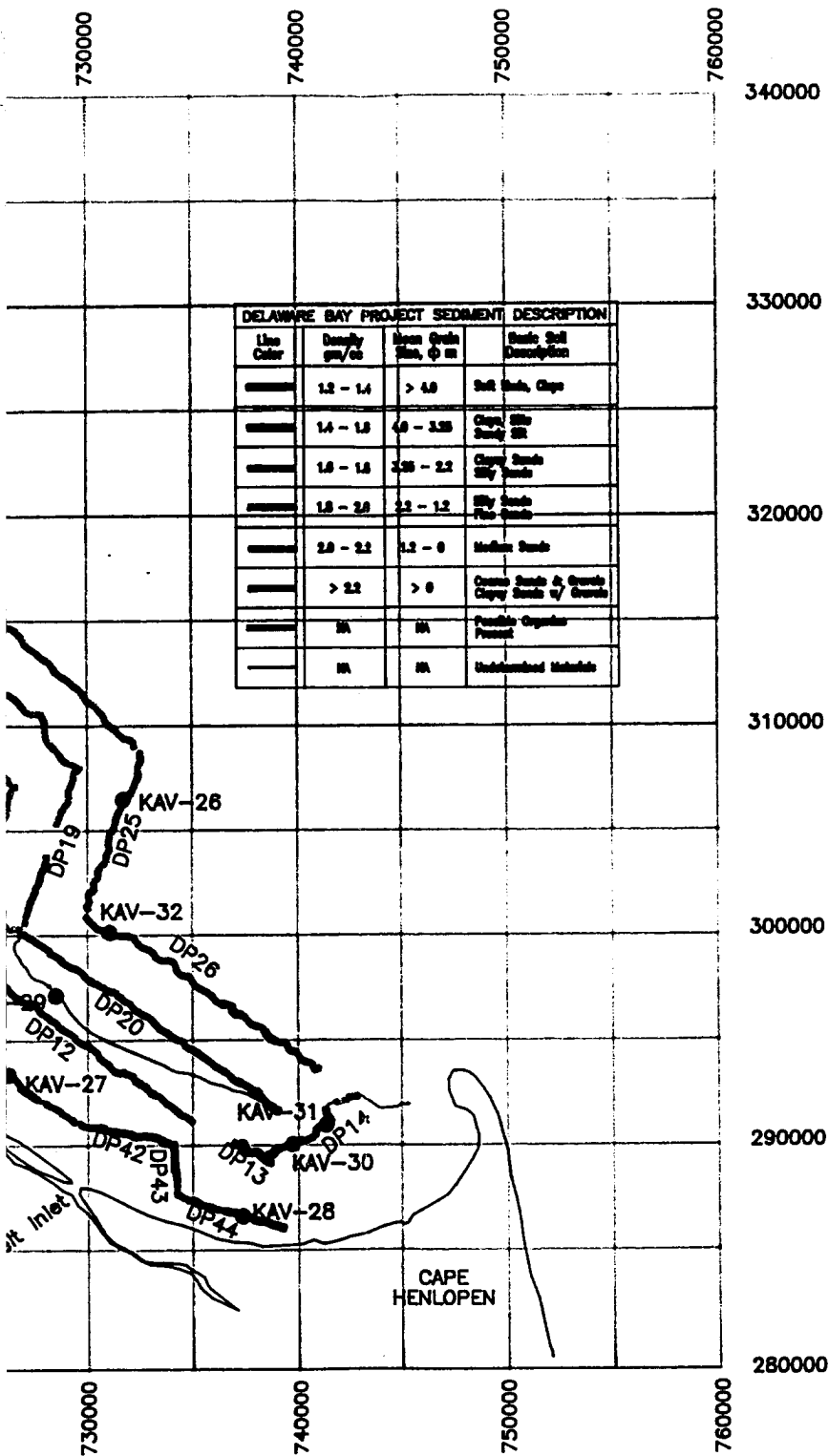


Figure 2. Detail of seismic lines and core locations from Mispillion River to Cape Henlopen, DE. showing surface sand types

2



in Mispillion River to Cape

sediment Types

7/8

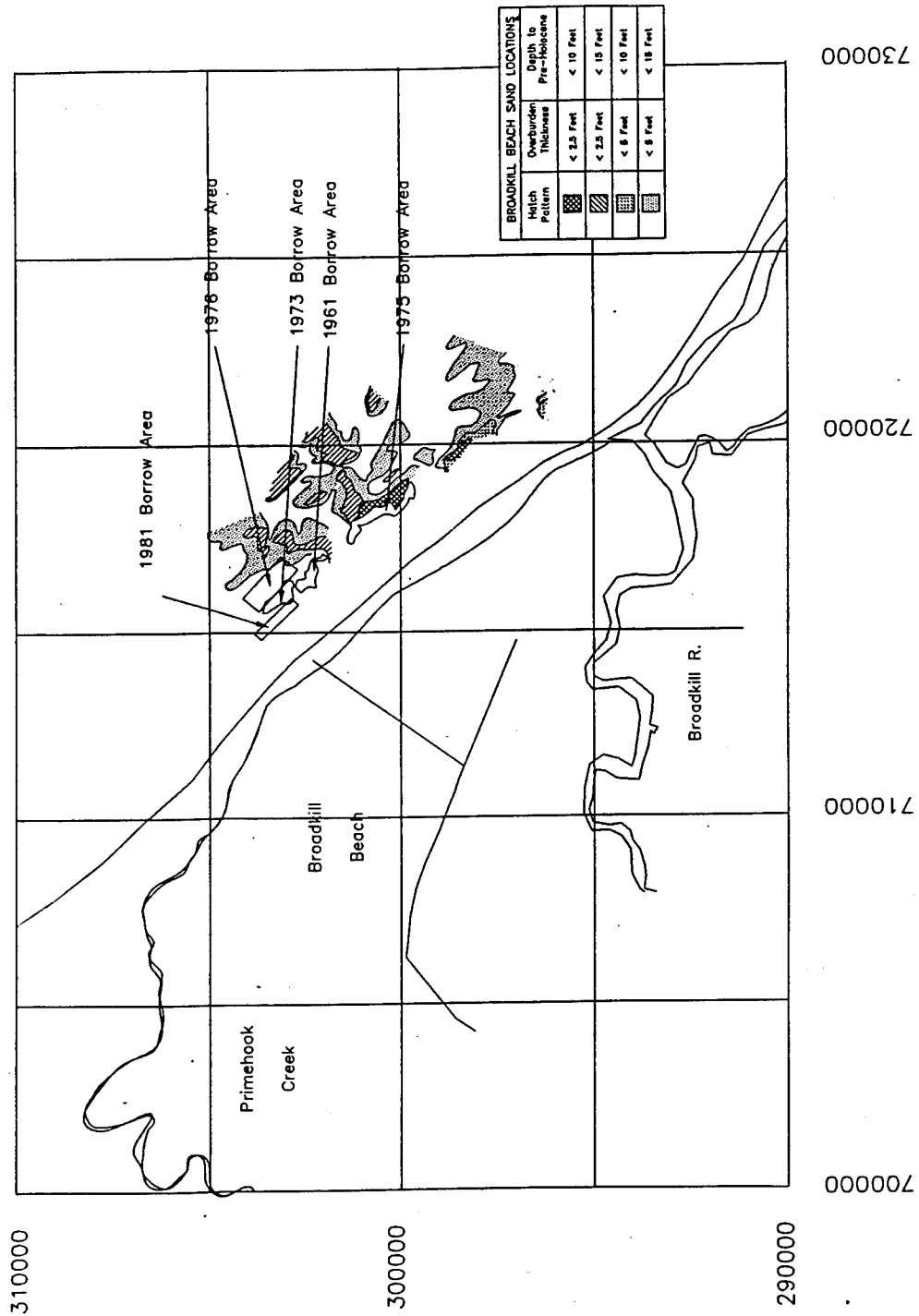


Figure 3. Location of inshore sand deposits and borrow areas (after Wethe (1982))

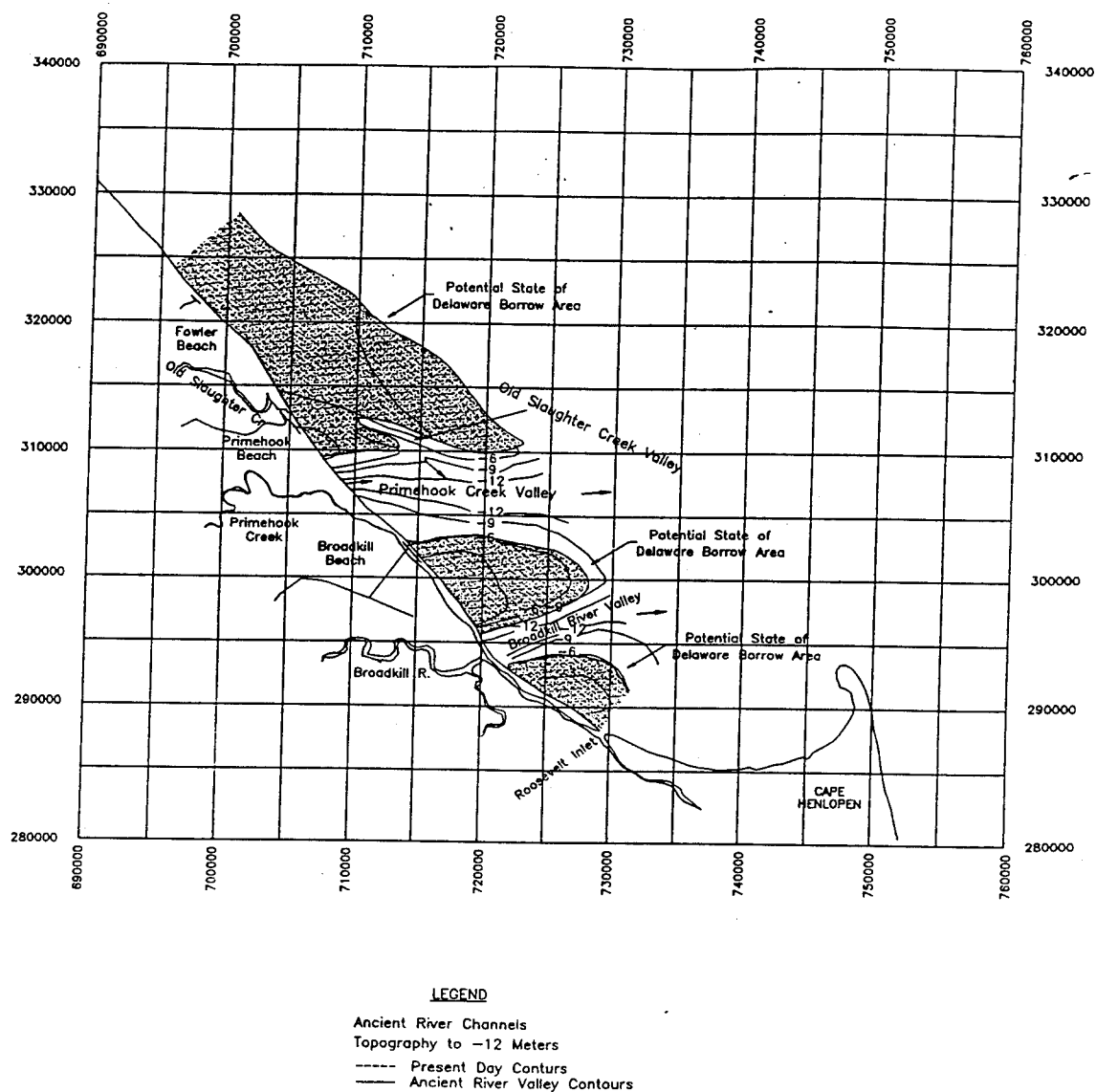


Figure 4. Location of sand shoals and ancient river valleys around Broadkill Beach (after Maley (1981))

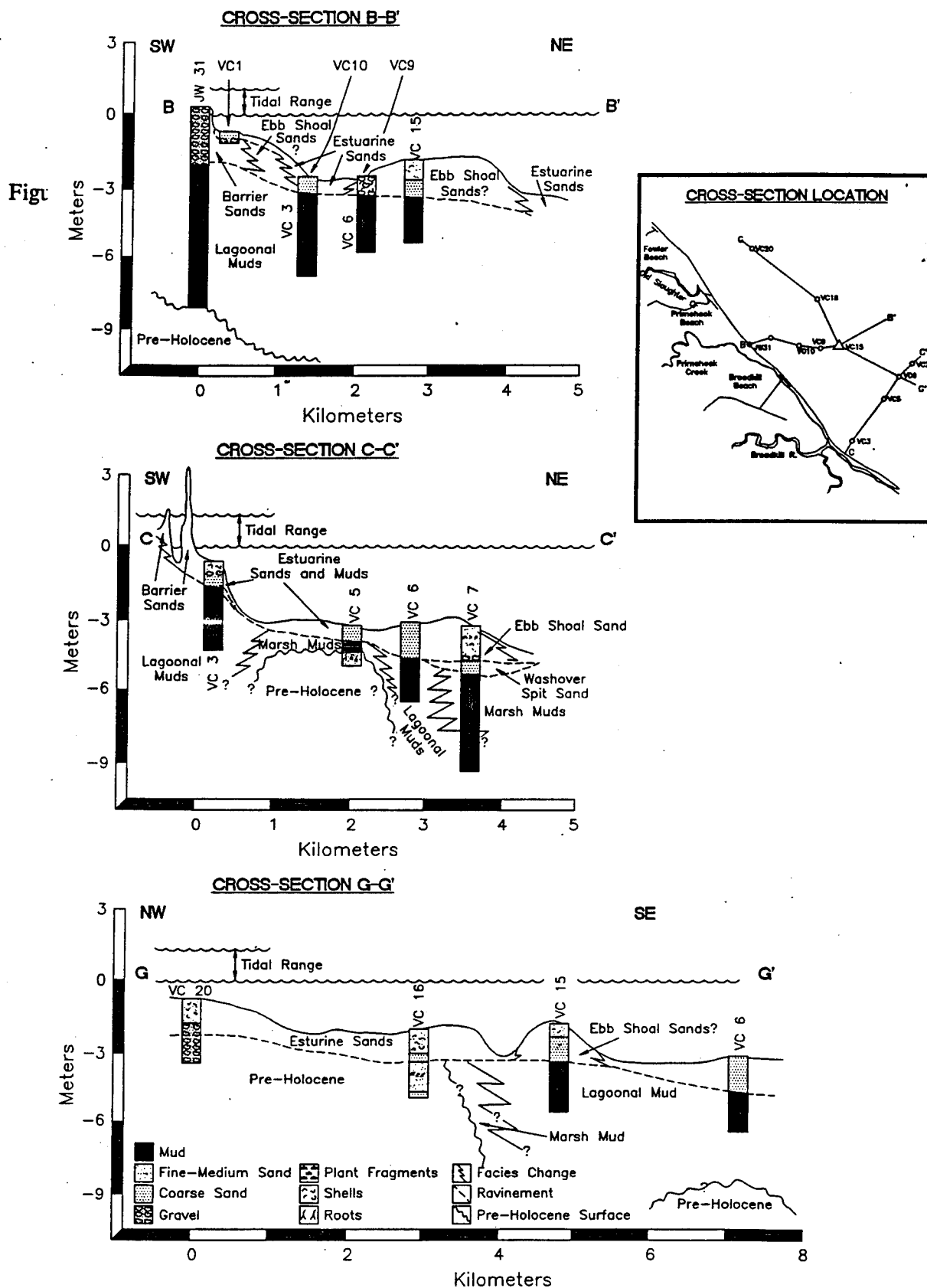


Figure 5. Cross sections of inshore area (after Maley (1981))

off Broadkill Beach. The red, yellow, and green areas on Figure 2 identify the sand areas, with magenta, blue and brown areas denoting a mix of mostly silt and mud. The area behind Cape Henlopen is a basin that contains very fine grain surficial sediments. Some of the cores in Breakwater Harbor show a coarser Pleistocene sand deposit around 10 feet below the surface in this area, but for the most part the surface material is too fine for beach nourishment.

Line DP35

Acoustic impedance analysis of four seismic track lines off Broadkill Beach show the stratigraphic distribution of sediment with depth. Line DP35 was the closest to shore. Figure 6 shows the typical pinger data collected on that line. From this data and additional information of three cores taken along this line at KAV-18, KAV-19 and KAV-20, Figure 7 show the sequence of shoals and river valleys. The southern part of the line contains medium to fine surficial sands. The sediments grade into silts at a depth of around 12-14 ft. This area corresponds to the ancestral Broadkill River Valley as described by Maley (1981).

Core KAV-18 is located in the area of the southern tip of the shoal identified by Maley (1981). The surface layer contains a poorly sorted fine gravel down to 3 ft. Below that the majority of the sediments are poorly sorted sands with some gravel to a depth of 13 ft. Below that depth the sediments are a fine silt. Appendix A gives the core log and sediment gradation curves for each vibracore location.

The central part of seismic line DP35 has a section of fine silty sands at the surface, located in a valley between two shoals. This is the landward extent of a wedge of fine material. Core KAV-19 located in this valley indicates that this silty sand material extends to a depth of at least 17.5 ft and supports the acoustic signature of fines at depth. Below a 3 ft thick poorly sorted medium sand layer, there are well sorted fine sands that have silt contents between 10 and 35 percent.

The northern portion of the line contains medium to fine sandy surficial sands. The northern part of this area is in another valley and the sediments grade into fine silts, possibly representing another ancestral river valley trending to the southeast. These fines may be outwash from an ancient more straight path of Slaughter Creek. Core KAV-20 in this northern area contains a thin gravely sand on the surface, with gravely clay lenses alternating with silts at depth. Most of the sediment has a D_{50} of around 0.05 mm (4.25 ϕ) from 1 ft down to 8 ft and gets only slightly coarser below that depth. Below 3 ft, the sediment has iron staining.

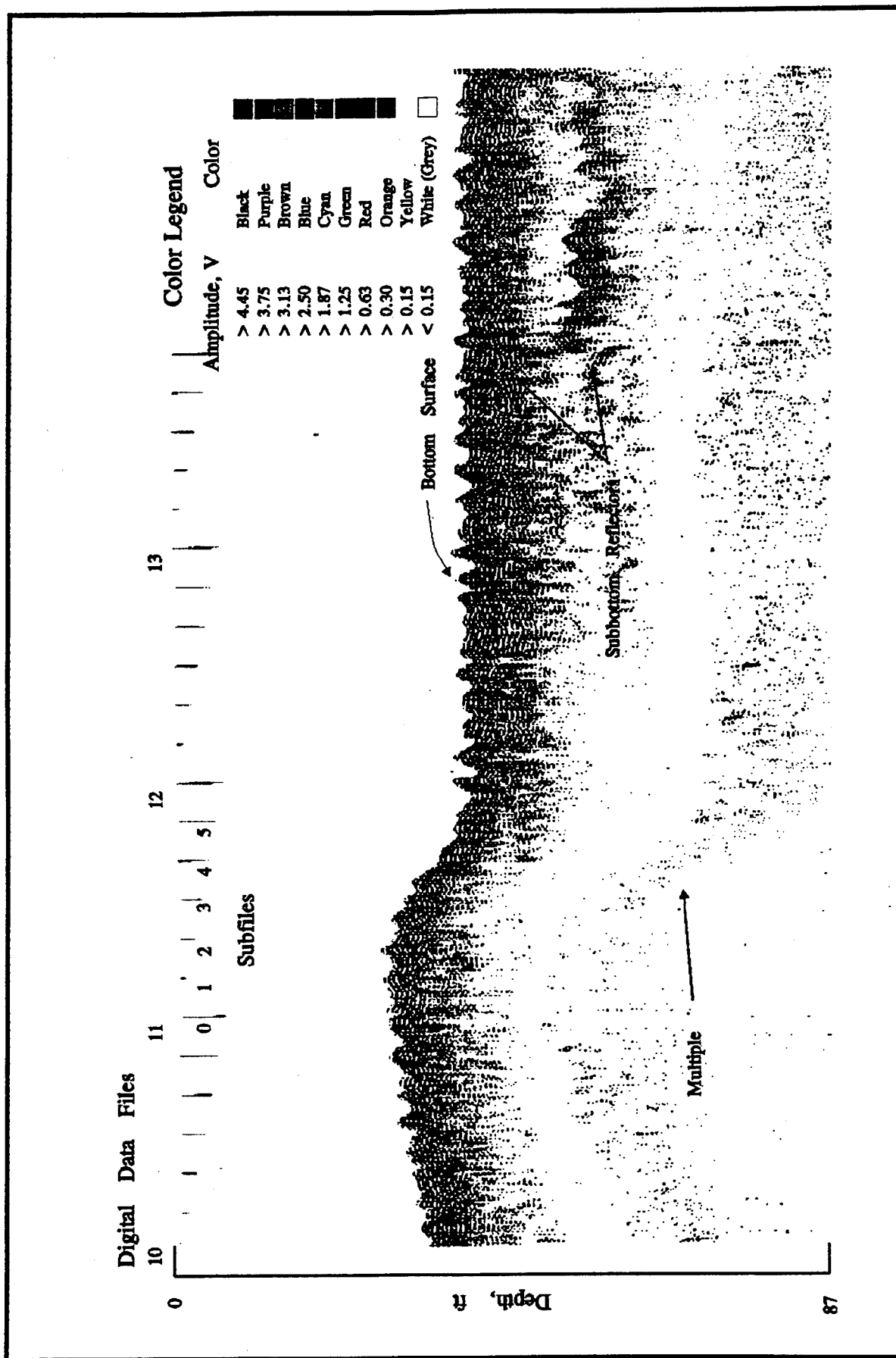
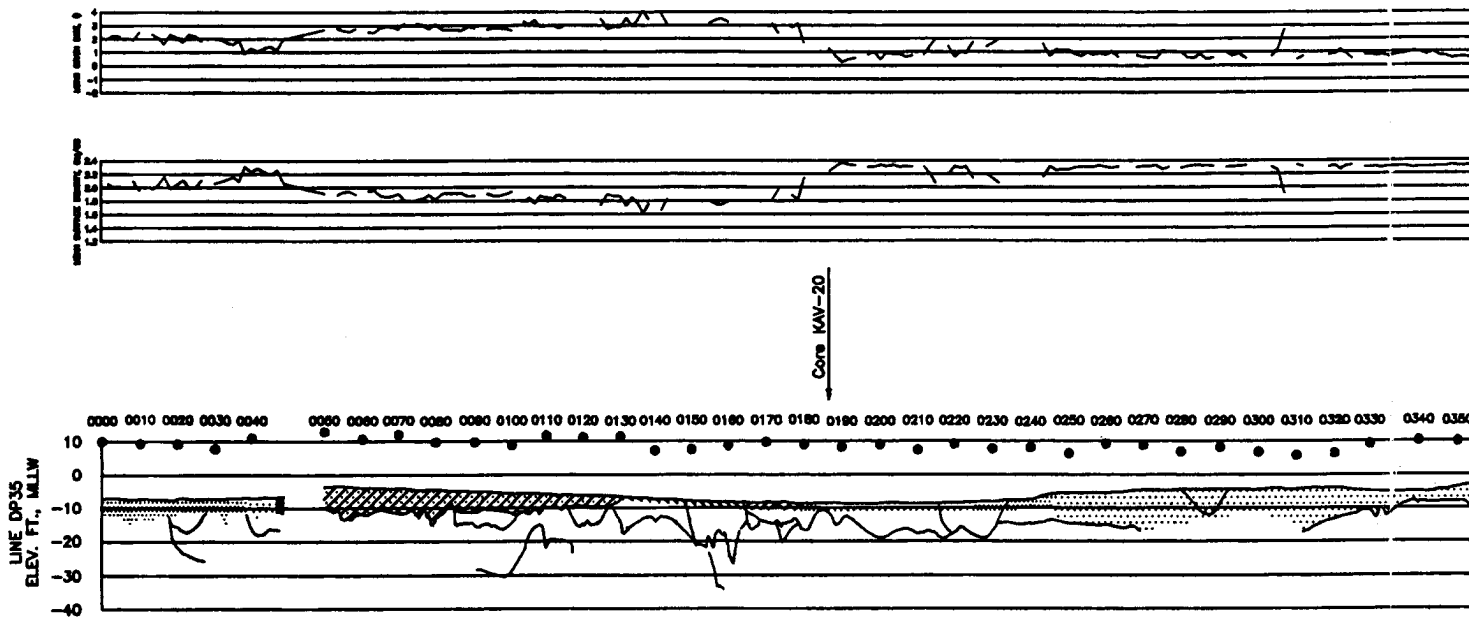


Figure 6. Example of typical pinger data record

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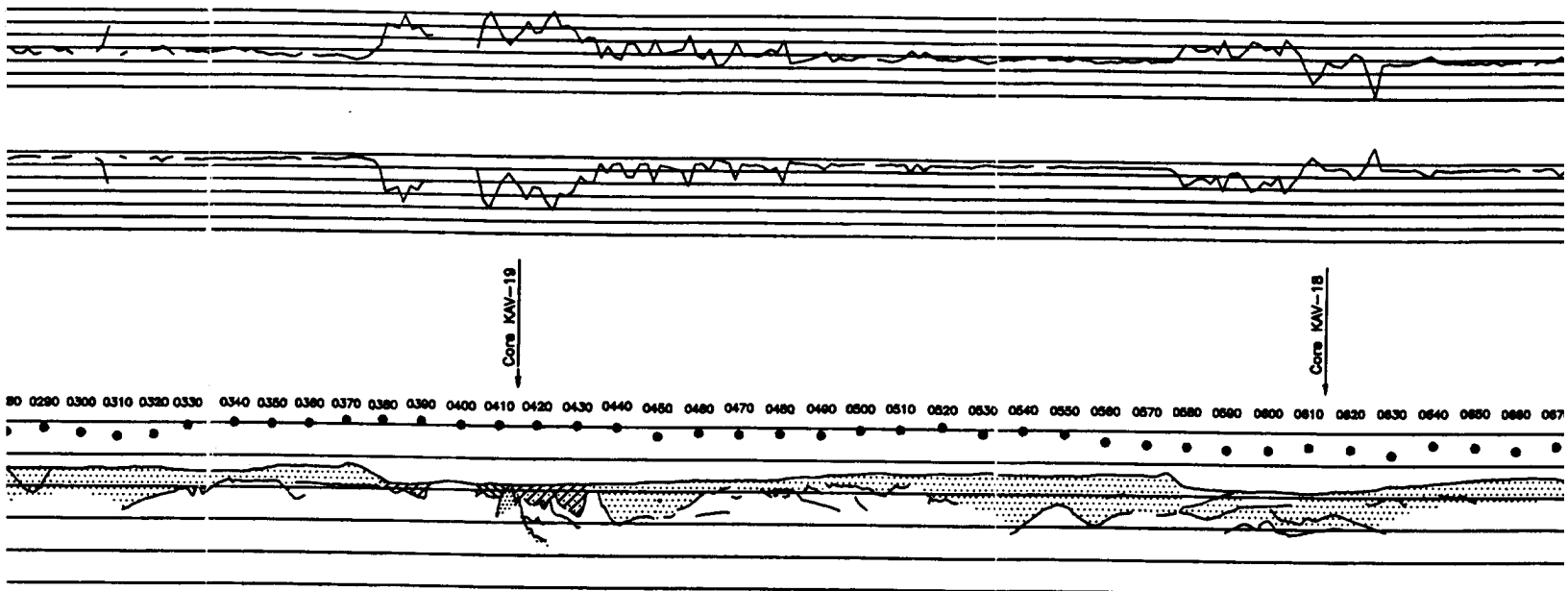









| DELAWARE BAY PROJECT | | |
|----------------------|---------------|-----------|
| Hatch Pattern | Density gm/cc | Mean Size |
| | 1.0 - 1.4 | > |
| | 1.4 - 1.8 | 4 - |
| | 1.8 - 1.8 | 3.2 |
| | 1.8 - .0 | 2.2 |
| | 2.0 - 2.2 | 1.2 |
| | > 2.2 | > |
| | > 2.4 | N |

Figure 7. Cross-section of Line DP35 with core locations

V.E.

②



| DELAWARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|------------------------------------------------------------------------------------|---------------|---------------------------|---------------------------------------------------|
| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
|  | 1.0 - 1.4 | > 4 | Soft Muds, Clays |
|  | 1.4 - 1.6 | 4 - 3.2 | Clays, Silts Sandy Silt |
|  | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands Silty Sands |
|  | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands Fine Sands |
|  | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
|  | > 2.2 | > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
|  | > 2.4 | N/A | Rock, Consolidated Clays |

V.E. = 50

WATERWAYS EXPERIMENTAL
CORPS OF ENGINEERS
VICKSBURG, MS

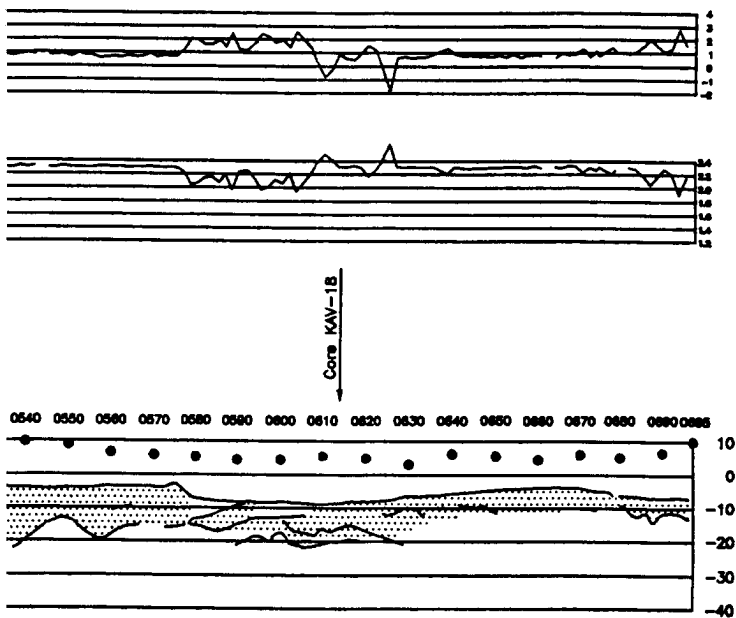
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SEDIMENT PROFILE
LINE DP35

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3



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|---------------------------------------------------------------------------|-------------------------|-------|
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| DELAWARE BAY PROJECT SEDIMENT PROFILE LINE DP35 | | |
| FILE NAME: DP35.DWG | | |
| SCALE: 1"=1000' | DATE: DECEMBER 11, 1985 | SHEET |

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Line DP10

The second seismic line seaward of the shoreline was Line DP 10 (Figure 8). The northern, central, and southern sections of this line have medium to fine sand surficial sediments located on shoals. Between the shoals, finer silty sediments were found in the valleys. Core KAV-21 was located on the central shoal area and contains well sorted medium to fine sands representing the shoal on the surface and to a depth of around 7 ft. Below that depth most of the sediment is composed of silty sand with some clay lenses around 9 ft. This sediment at depth is finer bay material underlying the shoal.

Line DP18

Further bayward Line DP18 (Figure 9) contains sand size material on the southern end shoal feature. Cores located along this line included KAV-22, KAV-23, and KAV 24. The central section of the line contains fine sands and silts. Core KAV-23 is the southern most core on this line and is located in a pocket of fine sand. This core is composed of mostly silty sand, with lenses of silt between 2 to 7.5 ft and below 7.5 ft a gravel component. Core KAV-22, located on the middle of the line contains silty sand with some clay material in the surface layers. Sandy silt is also present within the upper 4 ft. From 4-8 ft, a well-sorted sand with from 10 to 20 percent silts was present.

Core KAV-24 is the northern most core and is located on the flank of a shoal which occupies the northern section of the line. The upper 5 ft of the core contains silty sand grading into well sorted medium to fine sands with between 2 and 10 percent silts. Between 5 and 14 ft, silt material is present with some sand-size material. Below 14 ft the gravel and sand content increases along with a silt layer.

Line DP24

The most bayward seismic line is Line DP24 (Figure 10). No cores were collected along this line. The acoustic impedance analysis indicated that the southern end of the line has a sandy shoal feature. The central section is a long valley, containing finer sediments. A shoal of sandy material is at the northern end of the line. This central valley may be related to an ancestral river valley, possibly associated with Slaughter Creek, north of the study area. A deeply incised channel is present on the seismic record cutting down to around 45 ft below the bay bed.

Line DP39

Line DP39 is almost shore normal, extending bayward from just south of Broadkill Beach. Figure 11 shows the cross-section of Line DP39 with core KAV-25 at the northeast end. The entire line is composed of medium sized sand.

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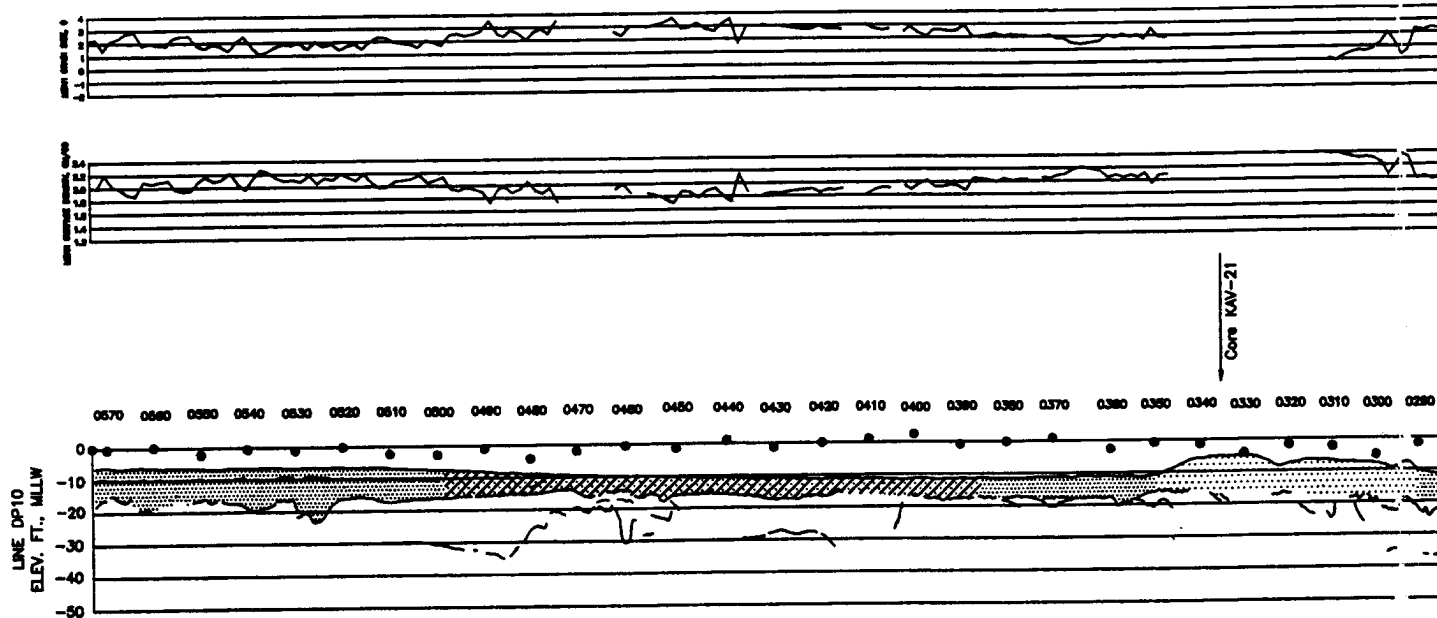
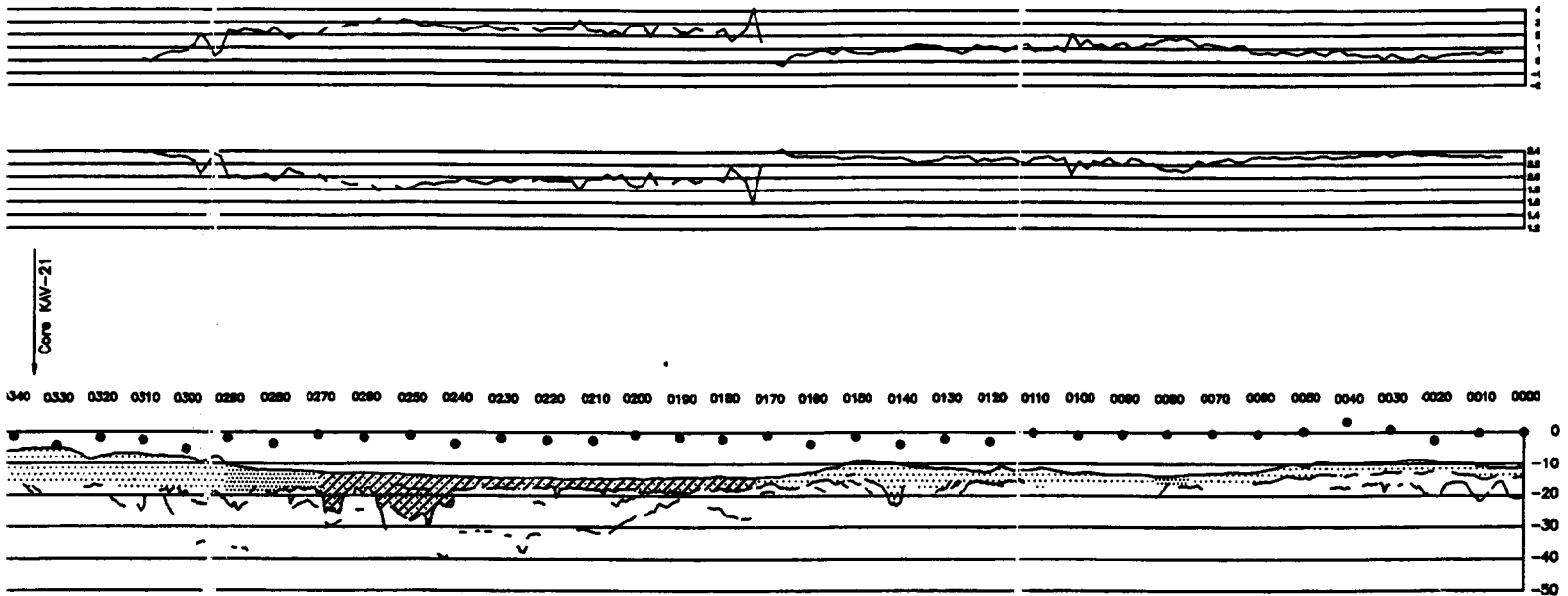


Figure 8. Cross-section of Line DP10 with core location

| DELAWARE BAY PROJECT S | | |
|------------------------|---------------|----------------------|
| Hatch Pattern | Density gm/cc | Mean Gr Size, ϕ |
| | 1.0 - 1.4 | > 4 |
| | 1.4 - 1.6 | - 3.5 |
| | 1.6 - 1.8 | 3.2 - 2 |
| | 1.8 - 2.0 | 2.2 - 1 |
| | 2.0 - 2.2 | 2 - 1 |
| | > 2.2 | > 0 |
| | > 2.4 | N/A |

V.C. =

2



| DELAWARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|-------------------------------------------|---------------|---------------------------|-------------------------------------------------|
| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
| | 1.0 - 1.4 | > 4 | Soft Muds, Clays |
| | 1.4 - 1.6 | - 3.2 | Clays, Silts, Silty Sand |
| | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands, Silty Sands |
| | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands, Fine Sands |
| | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
| | > 2.2 | > 0 | Coarse Sands & Gravels, Clayey Sands w/ Gravels |
| | > 2.4 | N/A | Rock, Consolidated Clays |

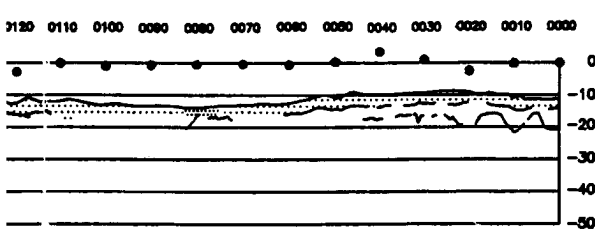
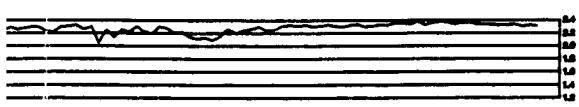
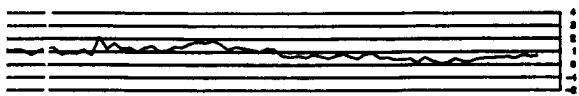
V.L. = 50

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE BAY PROJECT
SEDIMENT PROFILE
LINE DP10

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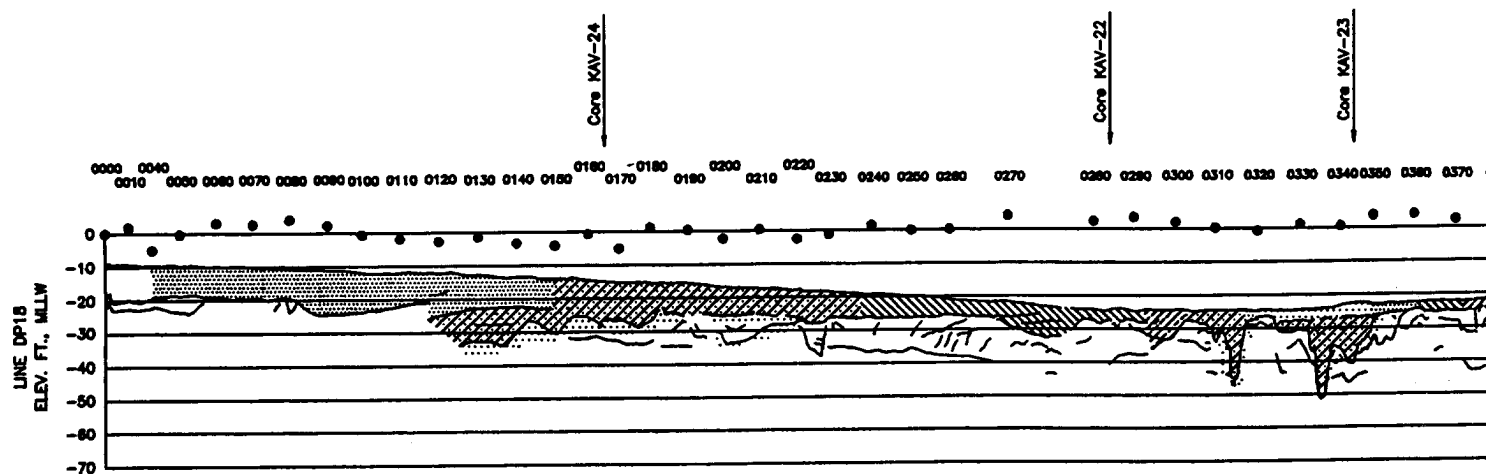
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| DELAWARE BAY PROJECT SEDIMENT PROFILE LINE DP10 | | |
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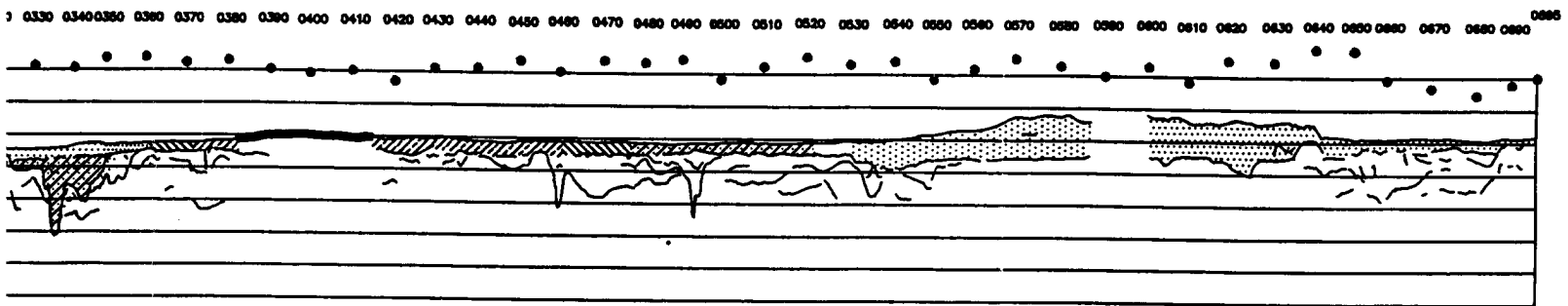
| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ n |
|---------------|---------------|---------------------------|
| | 1.0 - 1.4 | > 4 |
| | 1.4 - 1.6 | 4 - 3.2 |
| | 1.6 - 1.8 | 3.2 - 2.2 |
| | 1.8 - 2.0 | 2.2 - 1.2 |
| | 2.0 - 2.2 | 1.2 - 0 |
| | > 2.2 | > 0 |
| | > 2.4 | N/A |

V.E. = 5

Figure 9. Cross-section of Line DP18 with core locations

2

Core KAV-23



| WARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|---------------------------------------|------------------|------------------------------|---------------------------------------------------|
| dh cm | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
| | 1.0 - 1.4 | > 4 | Soft Mud, Claye |
| | 1.4 - 1.6 | 4 - 3.2 | Clays, Silts Sandy Silt |
| | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands Silty Sands |
| | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands Fine Sands |
| | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
| | > 2.2 | > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
| | > 2.4 | N/A | Rock, Consolidated Clays |

V.E. = 50

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

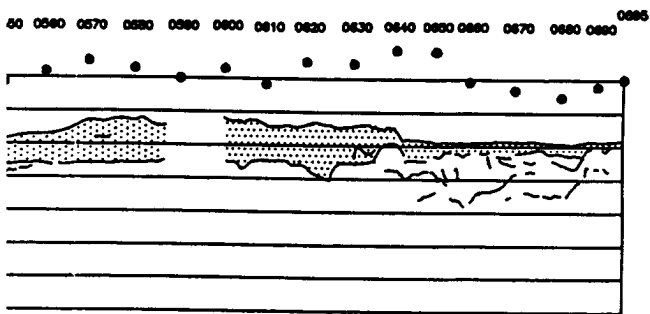
DELAWARE BAY
SEDIMENT PROFILE
LINE DP18

FILE NAME: DP18.DWG

SCALE: 1"=1000' DATE: DECEMBER 11, 1995 SHEET

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13



| | | |
|---------------------------------------------------------------------------|-------------------------|-------|
| WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180 | | |
| DELAWARE BAY SEDIMENT PROFILE LINE DP18 | | |
| FILE NAME: DP18.DWG | | |
| SCALE: 1"=1000' | DATE: DECEMBER 11, 1995 | SHEET |

21/22

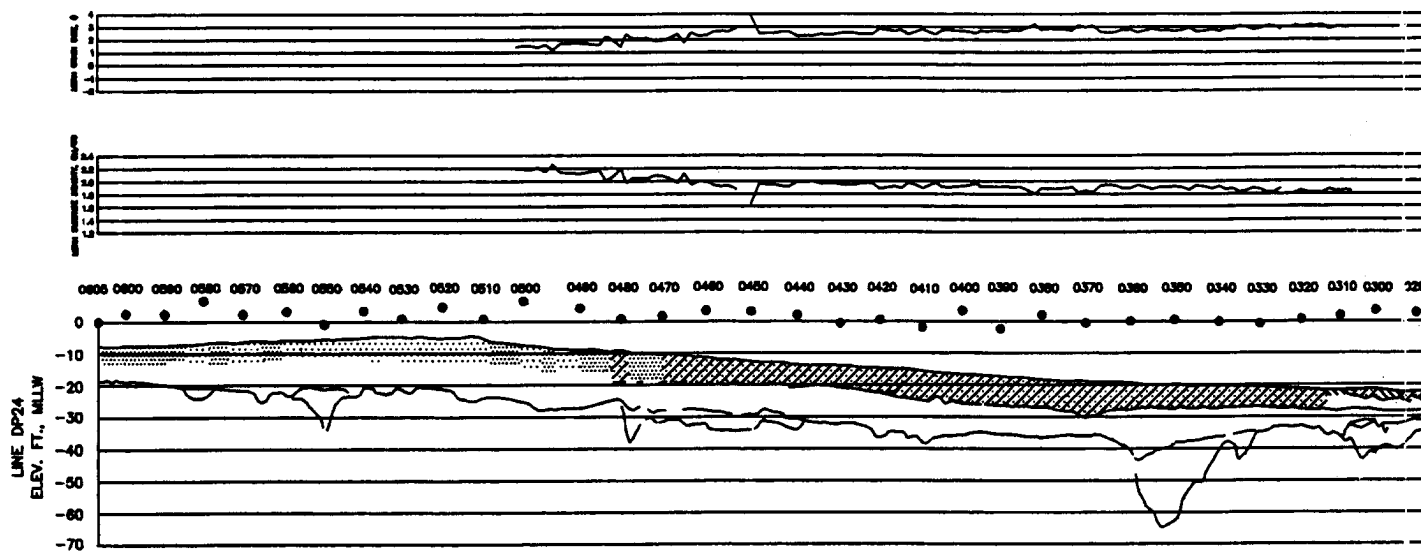
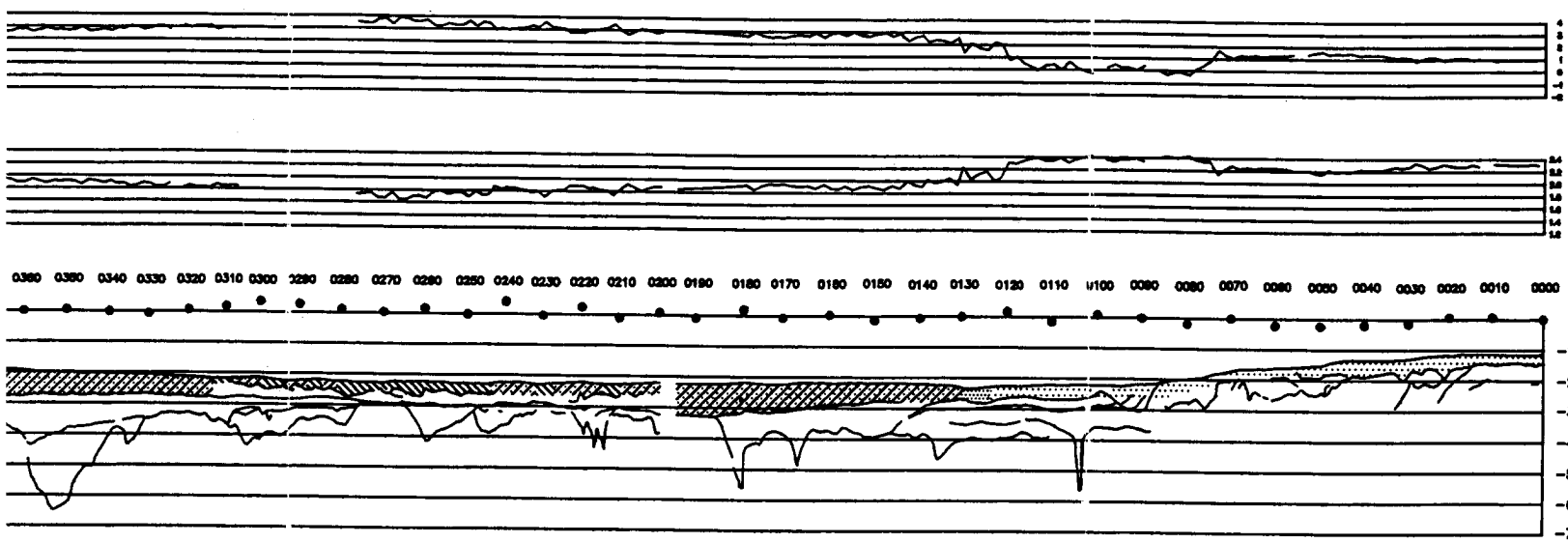


Figure 10. Cross-section of Line DP24

| DELAWARE BAY PROJECT | | |
|----------------------|---------------|-------------------|
| Hatch Pattern | Density gm/cc | Mean Size, ϕ |
| | 1.0 - 1.4 | > 4 |
| | 1.4 - 1.8 | 4 - 3 |
| | 1.8 - 1.8 | 3.2 - |
| | 1.8 - 2.0 | 2.2 - |
| | 2.0 - 2.2 | 1.2 - |
| | > 2.2 | > 0 |
| | > 2.4 | N/A |

V.E. =

72



| DELAWARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|-------------------------------------------|---------------|---------------------------|---------------------------------------------------|
| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
| | 1.0 - 1.4 | > 4 | Soft Mud, Claye |
| | 1.4 - 1.6 | 4 - 3.2 | Clays, Silts Sandy Silt |
| | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands Silty Sands |
| | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands Fine Sands |
| | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
| | > 2.2 | > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
| | > 2.4 | N/A | Rock, Consolidated Clays |

V.E. = 50

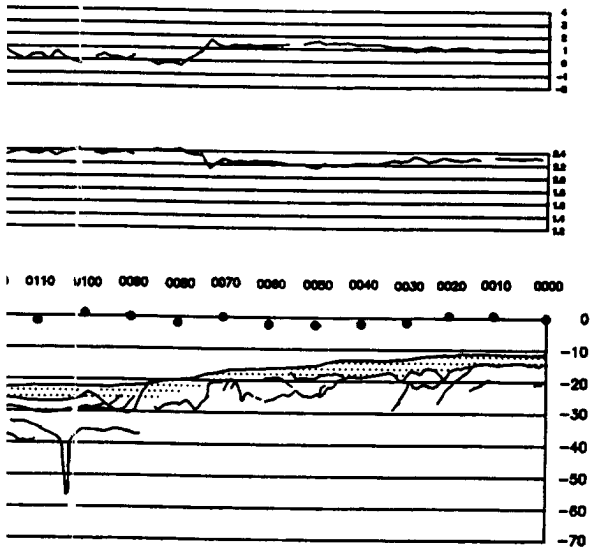
WATERWAYS EXPERIMENT S
CORPS OF ENGINEERS
VICKSBURG, MS 39181

DELAWARE BAY PROJECT
SEDIMENT PROFILE
LINE DP24

FILE NAME: DP24.DWG
SCALE: 1"=1000' DATE: DECEMBER 11, 1985 SHEET

23/24

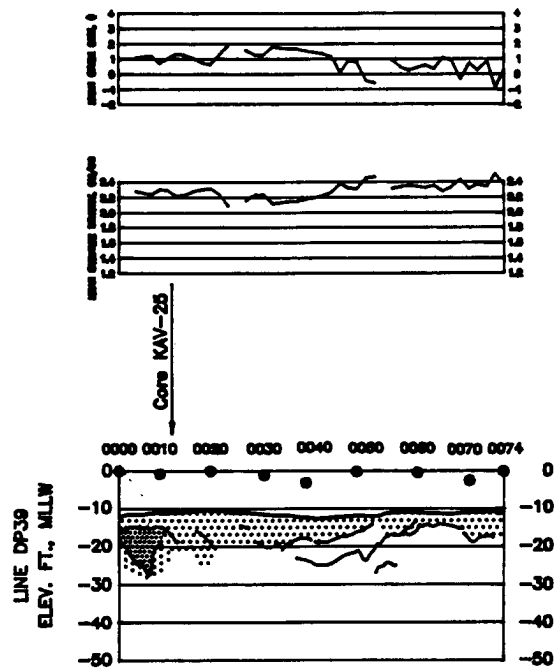
3



| | | |
|---------------------------------------------------------------------------|-------------------------|-------|
| WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180 | | |
| DELAWARE BAY PROJECT SEDIMENT PROFILE LINE DP24 | | |
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23/24

1



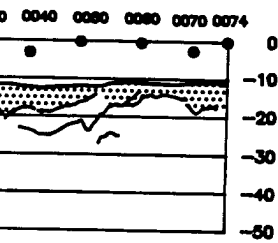
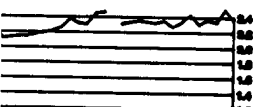
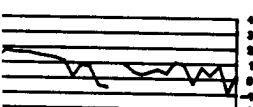
| DELAWARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|-------------------------------------------|---------------|---------------------------|-------------------------------------------------|
| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
| | 1.0 - 1.4 | > 4 | Soft Mud, Clays |
| | 1.4 - 1.8 | 4 - 3.2 | Clays, Silts, Sandy Silts |
| | 1.8 - 1.8 | 3.2 - 2.2 | Clayey Sands, Silty Sands |
| | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands, Fine Sands |
| | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
| | > 2.2 | > 0 | Coarse Sands & Gravels, Clayey Sands w/ Gravels |
| | > 2.4 | N/A | Rock, Consolidated Clays |

V.E. = 50

Figure 11. Cross-section of Line DP39 with core location

| |
|---------------------------------|
| WATERWAYS CORPS VICKSBURG |
| DELAWARE SEDIMENT L |
| FILE NAME: DP39.DWG |
| SCALE: 1"=1000' DATE: 0 |

2



CT SEDIMENT DESCRIPTION

| on Grain size, ϕ m | Basic Soil Description |
|----------------------------|---------------------------------------------------|
| > 4 | Soft Mud, Clays |
| - 3.2 | Clays, Silts Sandy Silts |
| - 2.2 | Clayey Sands Silty Sands |
| - 1.2 | Silty Sands Fine Sands |
| 2 - 0 | Medium Sands |
| > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
| N/A | Rock, Consolidated Clays |

= 50

| | | |
|---------------------------------------------------------------------------|-------------------------|-------|
| WATERWAYS EXPERIMENT STATION CORPS OF ENGINEERS VICKSBURG, MS 39180 | | |
| DELAWARE BAY PROJECT SEDIMENT PROFILE LINE DP39 | | |
| FILE NAME: DP39.DWG | | |
| SCALE: 1"=1000' | DATE: DECEMBER 11, 1998 | SHEET |

25/26

This core is in the area of the ancestral Primehook River Valley. The upper 2 ft of the core contained sand material, with some shells and gravel-size material. Below 3 ft the sands graded into silt-size material, possibly the lagoonal mud deposits described in the cross-section G-G' in Figure 5.

Line DP11

Line DP11 runs perpendicular to the Primehook River valley axis. The cross-section is shown in Figure 12. No cores were taken along this line. The acoustic impedance analysis of the seismic data indicated that all of the surface sediment was medium to fine sands. A deep subbottom reflector in the center of the line may be associated with the ancestral Primehook River Valley. Line G-G' (Figure 5) crosses line DP11 and from that data the subbottom may be composed of fine lagoonal muds under the surficial sands.

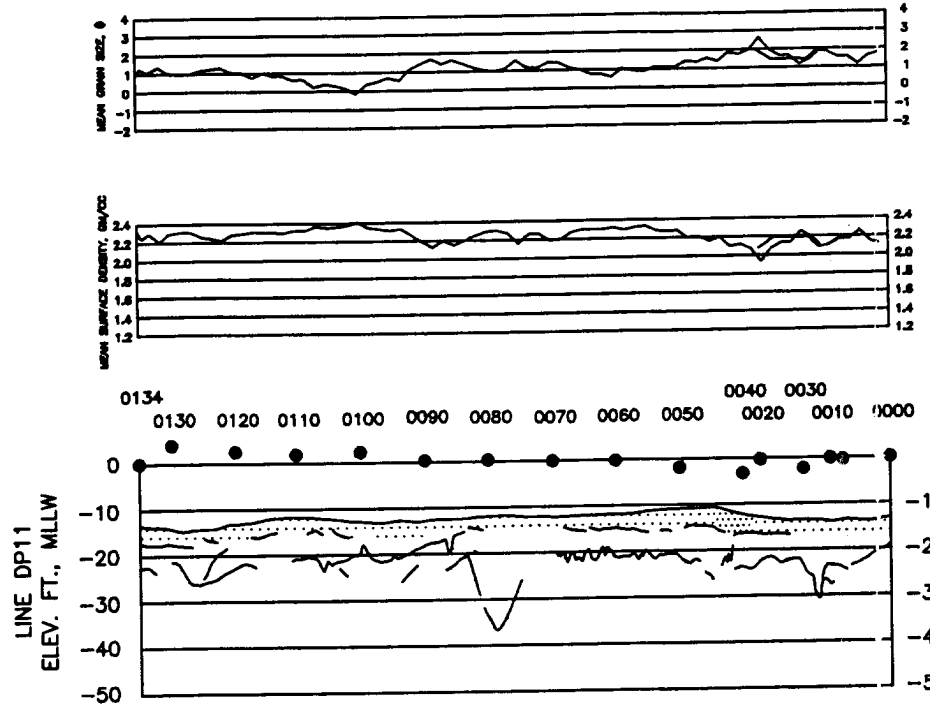
Line DP19






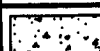

Parallel to line DP11 but further bayward was line DP19. Figure 13 shows the cross-section of Line DP19. No cores were collected along this line and some data was missing from the center of the line. The acoustic signature indicates fine to medium sands in the surficial layer. Again the underlying layers are probably the lagoonal mud deposit of Maley (1981).

Line DP 25

The most bayward seismic line of this group was Line DP25. Figure 14 shows the cross-section of Line DP25 with core KAV-26. The surficial sediments increase in grain-size from fine silty sand on the landward end to medium sand on the shoal on the bayward end of the line. Core KAV-26 was located on the northeastern end of the line, on the southern edge of the sand shoal next to the ancestral Primehook River Valley. Most of the core contains well sorted sands, with some silt. Some gravel material was found in the lower section of the core.

①

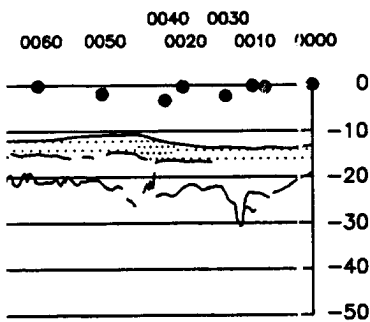
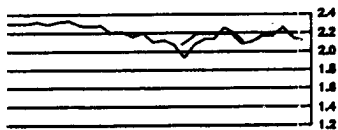
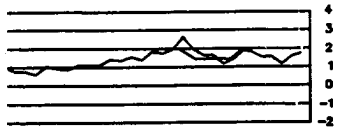


| DELAWARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|-------------------------------------------------------------------------------------|---------------|---------------------------|---------------------------------------------------|
| Hatch Pattern | Density gm/cc | Mean Grain Size, Φ m | Basic Soil Description |
|  | 1.0 - 1.4 | > 4 | Soft Muds, Clays |
|  | 1.4 - 1.6 | 4 - 3.2 | Clays, Silts Sandy Silt |
|  | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands Silty Sands |
|  | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands Fine Sands |
|  | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
|  | > 2.2 | > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
|  | > 2.4 | N/A | Rock, Consolidated Clays |

V.E. = 50

Figure 12. Cross-section of Line DP11

2



| MENT DESCRIPTION |
|---------------------------------------------------|
| Basic Soil Description |
| Soft Muds, Clays |
| Clays, Silts Sandy Silt |
| Clayey Sands Silty Sands |
| Silty Sands Fine Sands |
| Medium Sands |
| Coarse Sands & Gravels Clayey Sands w/ Gravels |
| Rock, Consolidated Clays |

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE BAY PROJECT
SEDIMENT PROFILE
LINE DP11

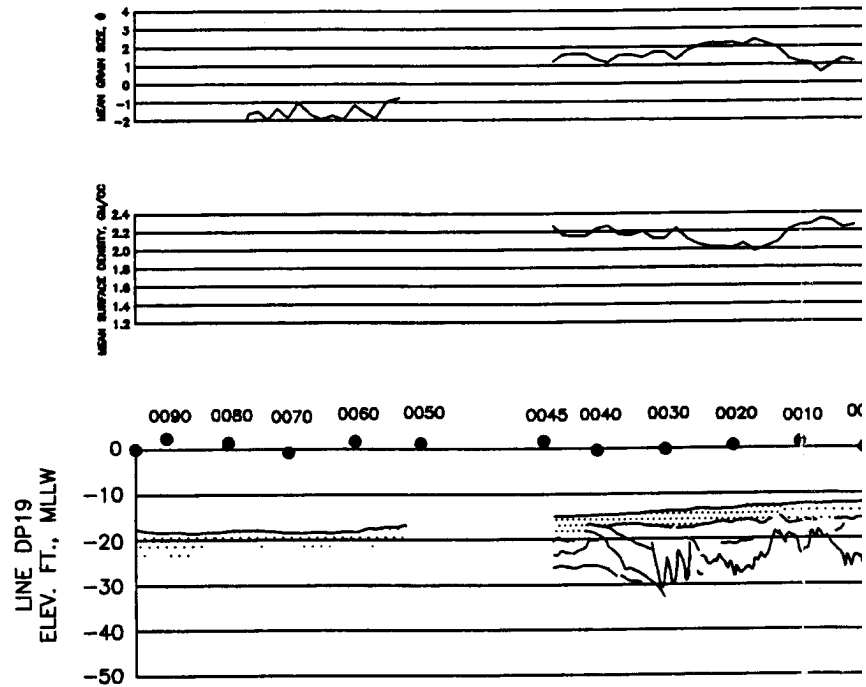
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


SCALE: 1"=1000'

DATE: DECEMBER 11, 1995

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1

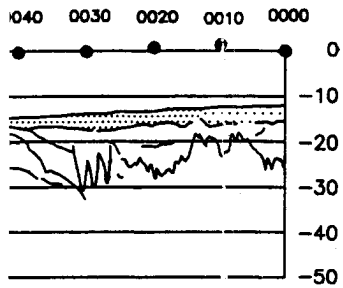
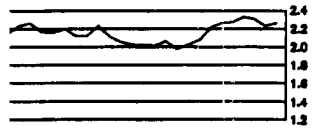
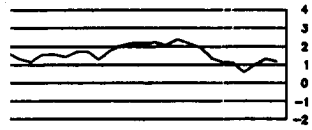


| DELAWARE BAY PROJECT SEDIMENT DESCRIPTION | | | |
|--------------------------------------------------------------------------------------|---------------|---------------------------|---------------------------------------------------|
| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
|  | 1.0 - 1.4 | > 4 | Soft Muds, Clays |
|  | 1.4 - 1.6 | 4 - 3.2 | Clays, Silts Sandy Silt |
|  | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands Silty Sands |
|  | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands Fine Sands |
|  | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
|  | > 2.2 | > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
|  | > 2.4 | N/A | Rock, Consolidated Clays |

V.E. = 50

Figure 13. Cross-section of Line DP19

2



| SOIL DESCRIPTION |
|---------------------------------------------------|
| Basic Soil Description |
| Soft Muds, Clays |
| Clays, Silts Sandy Silt |
| Clayey Sands Silty Sands |
| Silty Sands Fine Sands |
| Medium Sands |
| Coarse Sands & Gravels Clayey Sands w/ Gravels |
| Rock, Consolidated Clays |

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

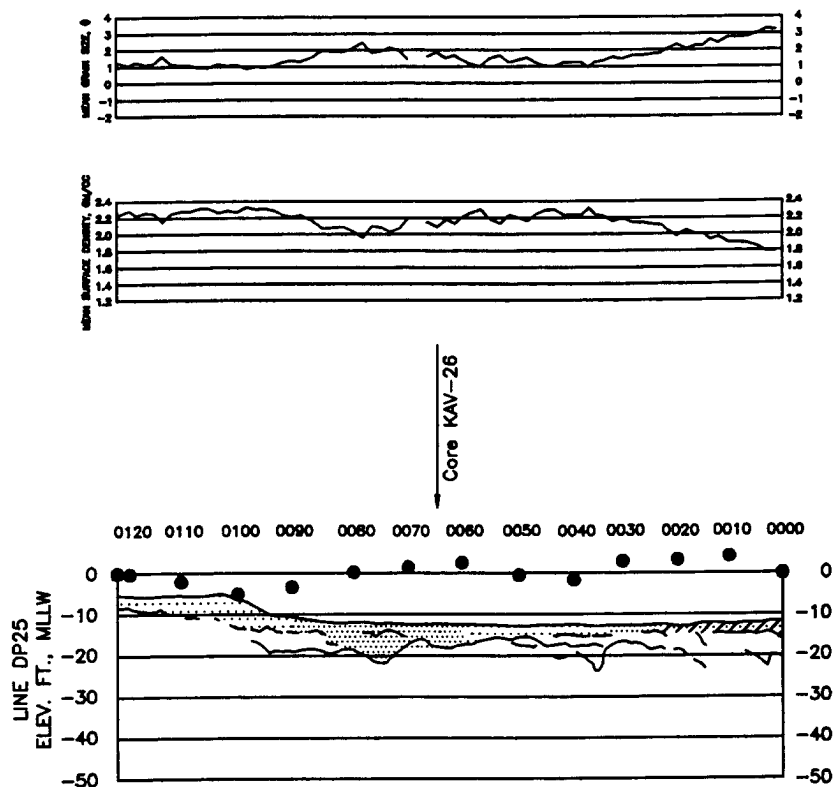
DELAWARE BAY PROJECT
SEDIMENT PROFILE
LINE DP19

FILE NAME: DP19.DWG

SCALE: 1"=1000' DATE: DECEMBER 11, 1995 SHEET

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1

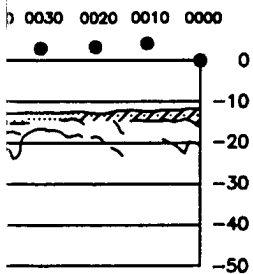
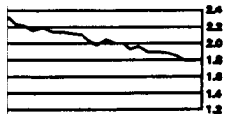
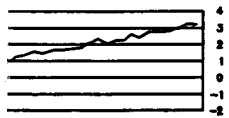


| Hatch Pattern | Density gm/cc | Mean Grain Size, ϕ m | Basic Soil Description |
|---------------|---------------|---------------------------|---------------------------------------------------|
| | 1.0 - 1.4 | > 4 | Soft Muds, Clays |
| | 1.4 - 1.6 | 4 - 3.2 | Clays, Silts Sandy Silt |
| | 1.6 - 1.8 | 3.2 - 2.2 | Clayey Sands Silty Sands |
| | 1.8 - 2.0 | 2.2 - 1.2 | Silty Sands Fine Sands |
| | 2.0 - 2.2 | 1.2 - 0 | Medium Sands |
| | > 2.2 | > 0 | Coarse Sands & Gravels Clayey Sands w/ Gravels |
| | > 2.4 | N/A | Rock, Consolidated Clays |

Figure 14. Cross-section of Line DP25 with core location

V.E. = 50

2



| DESCRIPTION |
|---------------------------|
| Basic Soil Description |
| Muds, Clays |
| Silts, Silty Silts |
| Sandy Sands |
| Sands |
| Gravelly Sands |
| Sands & Gravels |
| Gravelly Sands w/ Gravels |
| Consolidated Clays |

WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MS 39180

DELAWARE BAY PROJECT
SEDIMENT PROFILE
LINE DP25

FILE NAME: DP25.DWG

SCALE: 1"=1000'

DATE: DECEMBER 11, 1995

SHEET

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4 Summary

Sediment in the lower Delaware Bay is controlled by the geologic processes of the Pleistocene regression and transgression and is modified by present-day coastal processes. The area of potential sand resources has been identified using seismic survey profiles and vibracores. The area identified as containing possible borrow areas is outlined in Figure 15. The thickness ranges from 3 ft on the inshore end to possibly 10 ft on the shoal areas offshore. The area is characterized by two shoal areas divided by valleys that correspond to pre-Holocene river valleys. These valleys are composed of fine material not suited for beach nourishment. The shoal areas are topographic highs and contain medium to fine sands, that are suitable for consideration to nourish Broadkill Beach.

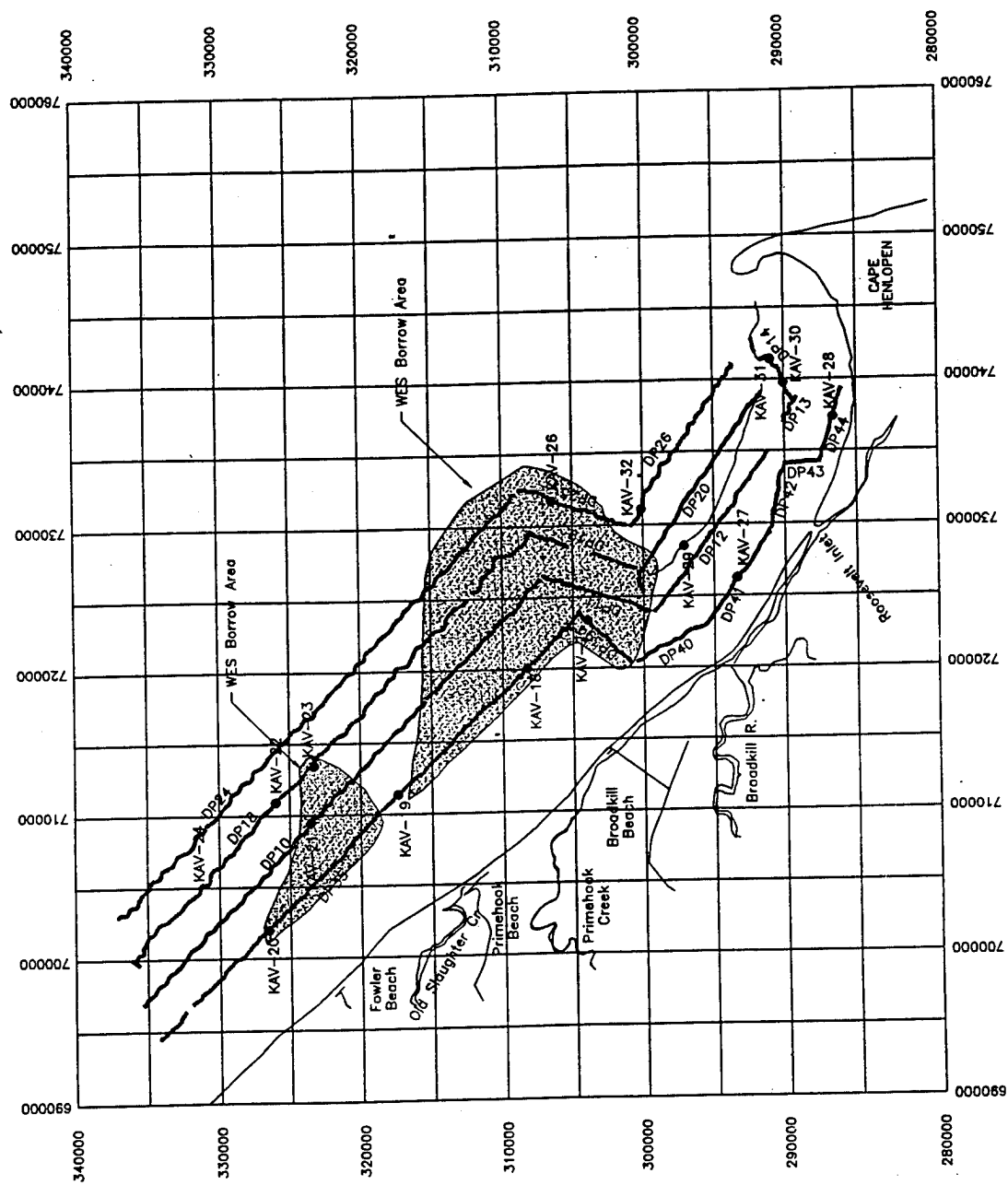


Figure 15. Area of potential sand resources

References

- Fletcher, C.H. III, Knebel, H.J., and Kraft, J.C. (1990). "Holocene evolution of an estuarine coast and tidal wetlands," *Geological Society of America Bulletin* 102, 283-297.
- Knebel, H.J., Fletcher, C.H. III, and Kraft, J.C. (1988). "Late Wisconsinan-Holocene paleogeography of Delaware Bay; A large coastal plain estuary," *Marine Geology* 83, 115-133.
- Maley, K. (1981). "A transgressive facies model in a shallow estuarine environment: The Delaware Bay nearshore zone, from Beach Plum Island to Fowler Beach," M.S. thesis, Geology Department, University of Delaware, Newark.
- McGee, R.G., Ballard, R.F., and Caulfield, D.D. (1995). "A technique to assess the characteristics of bottom and subbottom marine sediments," Technical Report DRP-95-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- McGee, R.G. "Geoacoustic study of Delaware River main channel," in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Wethe, C.A. (1984). "The suitability of offshore sand deposits for use as beach fill at Broadkill Beach," Technical Report WEA-05-84, Delaware Division of Soil and Water Conservation, Dover, DE.
- Wethe, C.A., De Sombre, K., Counts, D.M., and Tinsman, C.H. (1982). "Sand sources for the renourishment of Broadkill Beach," Technical Report MSL-01-82, College of Marine Studies, University of Delaware, Lewes.

Appendix A

Core Logs and Gradation Curves

Appendix A contains the core logs and gradation curves supplied by the U.S. Army Corps of Engineers, South Atlantic Division Sediment Laboratory. The core logs list the core length, material description and the location of the sediment samples collected within the core for grain-size analysis and selected samples that were analyzed for density. The gradation curves are provided for each sample analyzed within each core. The sample number and depth range of the channel sample correspond to the listing on the core log comments column.

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060



| Project: DELAWARE BAY | | | Boring No. KAV-18 | |
|----------------------------------------------------------------|-----------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Location: VIBRA CORE SAMPLES | | | Lab No. 184/925 | |
| Boring Depth (ft): 15.20 | | Elevation: | Work order: 7476 | |
| Datum/Notes: See grain size data on enclosed gradation curves. | | | Requisition: CENAP-95-707 | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | TAN, SANDY POORLY GRADED GRAVEL (GP). | (Density Units = pcf) SA (A) 1.2 - 2.2' |
| | 2 | | | |
| | 3 | | ----- | |
| | 4 | | TAN, POORLY GRADED SILTY SAND (SP-SM). | SA D-1 3.0 - 3.5' WET DEN. = 128.9, DRY DEN. = 119.1, MC = 8.2% |
| | 5 | | ----- | |
| | 6 | | | |
| | 7 | | | |
| | 8 | | TAN, GRAVELLY POORLY GRADED SILTY SAND (SP-SM), WITH A TRACE OF MICA. | SA D-2 7.5 - 8.0' WET DEN. = 139.5, DRY DEN. = 132.7, MC = 6.0% |
| | 9 | | | |
| | 10 | | | |
| | 11 | | ----- | |
| | 12 | | TAN AND GRAY, SILTY SAND (SM), WITH A LITTLE GRAVEL SIZES. | SA (B) 11.9 - 12.3' |
| | 13 | | ----- | |
| | 14 | | TAN AND GRAY, MICACEOUS INORGANIC SILT LOW LL (ML), WITH A LITTLE SAND SIZES, SAND SIZES MORE PREDOMINANT BOTTOM 0.4 OF SAMPLE. | SA D-3 13.3 - 13.9' WET DEN. = 127.1, DRY DEN. = 102.4 MC = 24.2% |
| | 15 | | ----- | |
| | 16 | | | |
| | 17 | | | |

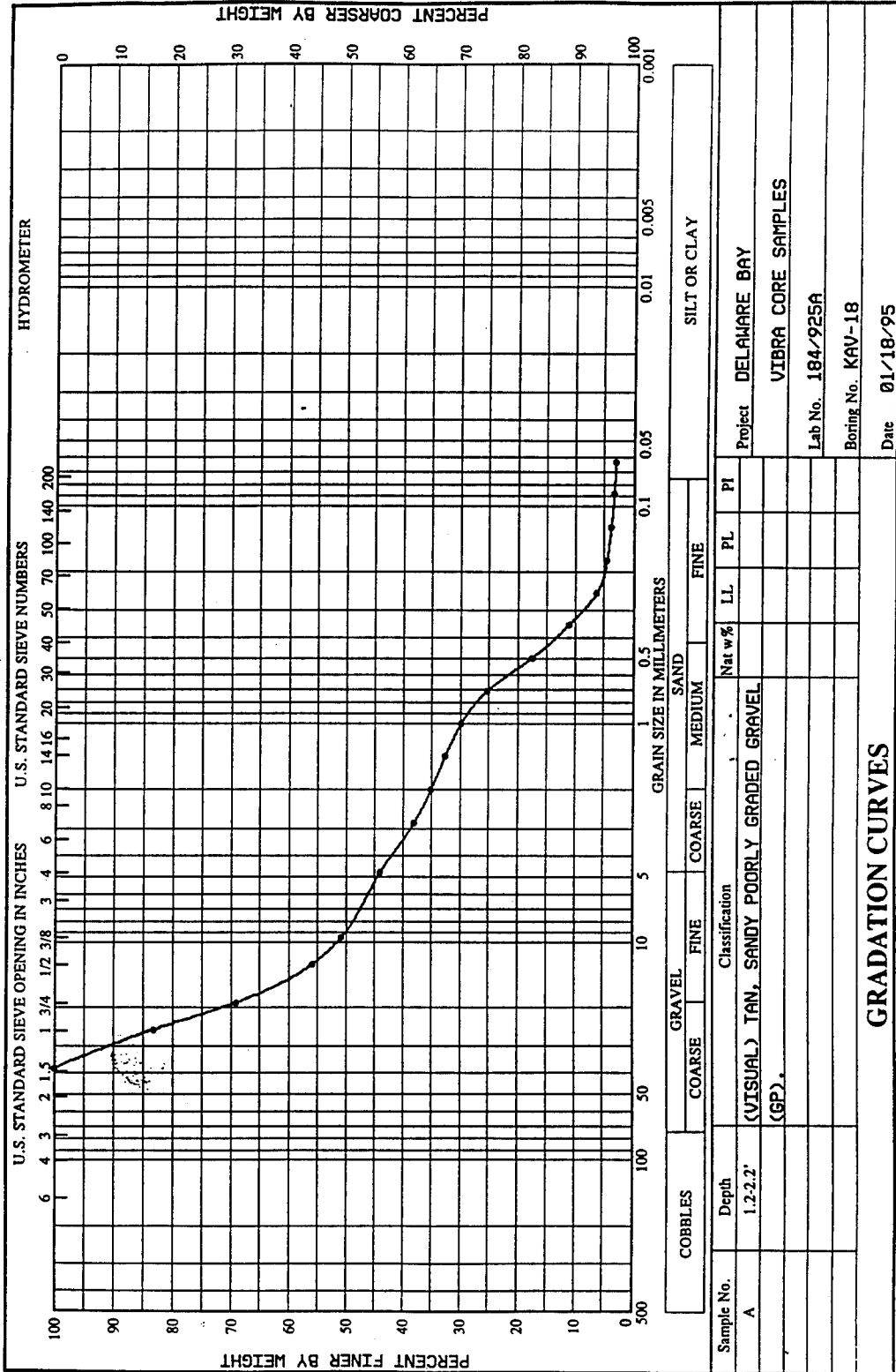
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LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

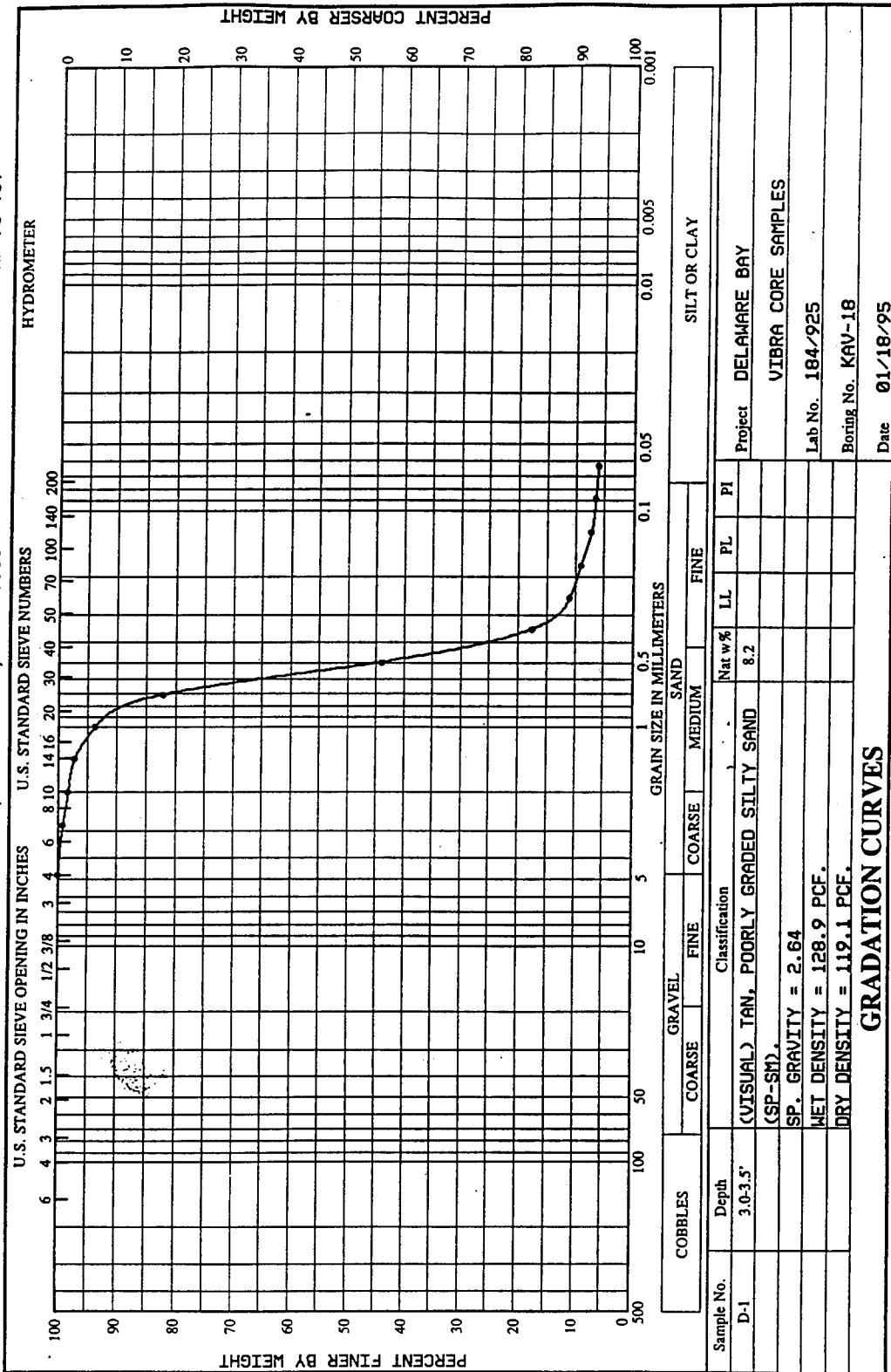
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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



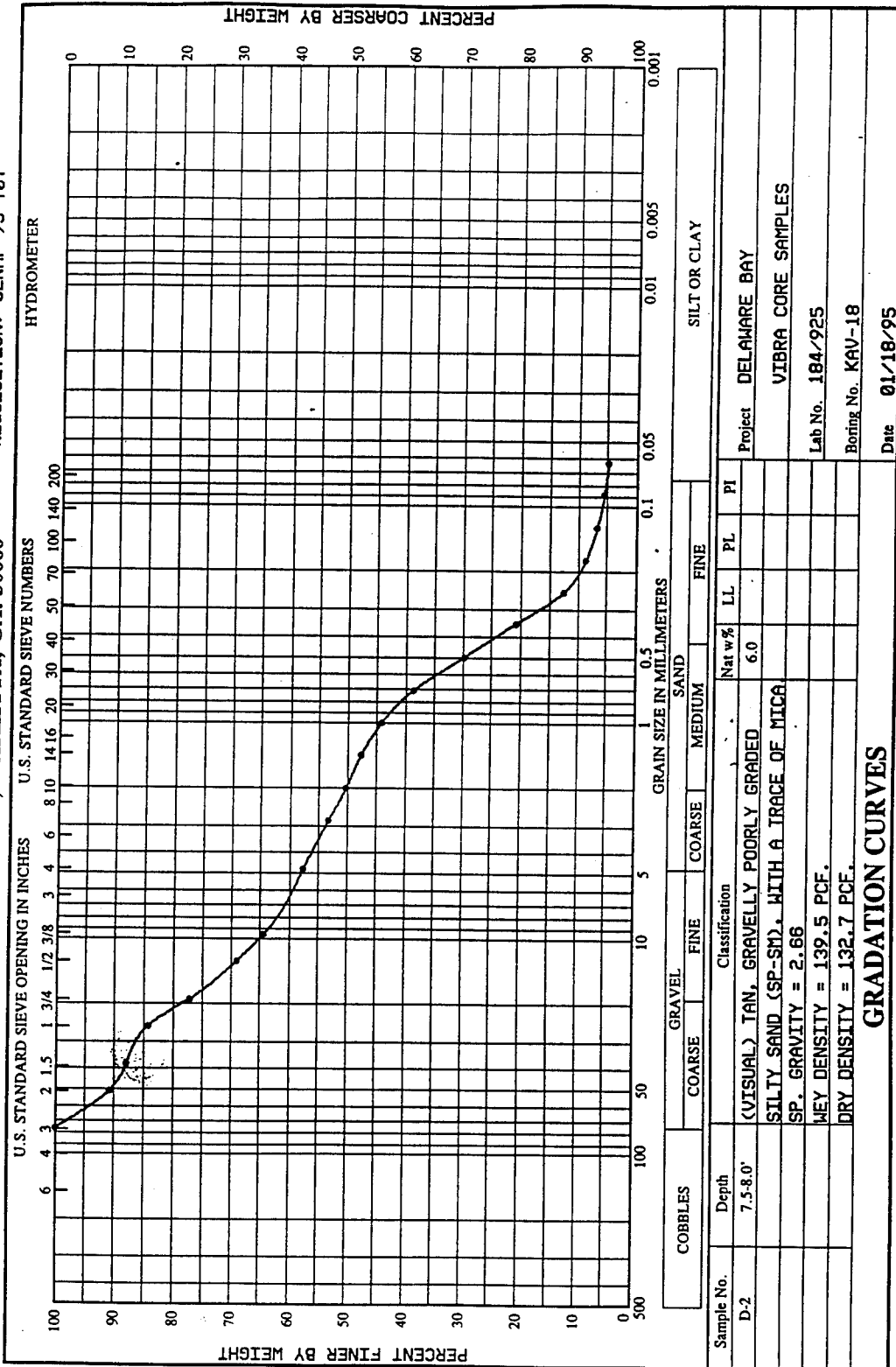
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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

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REQUISITION: CENAP-95-707



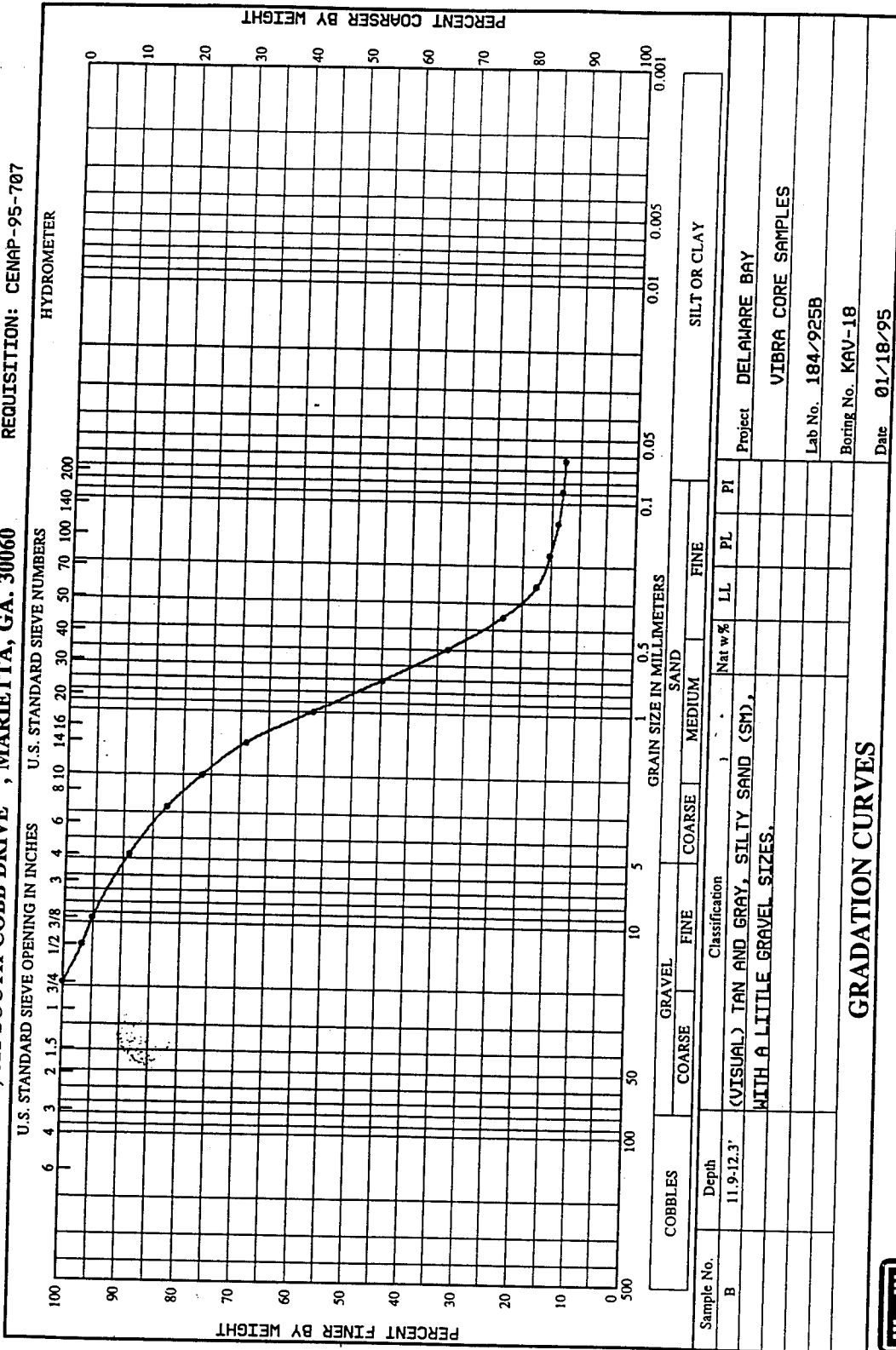
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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

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REQUISITION: CENAP-95-707



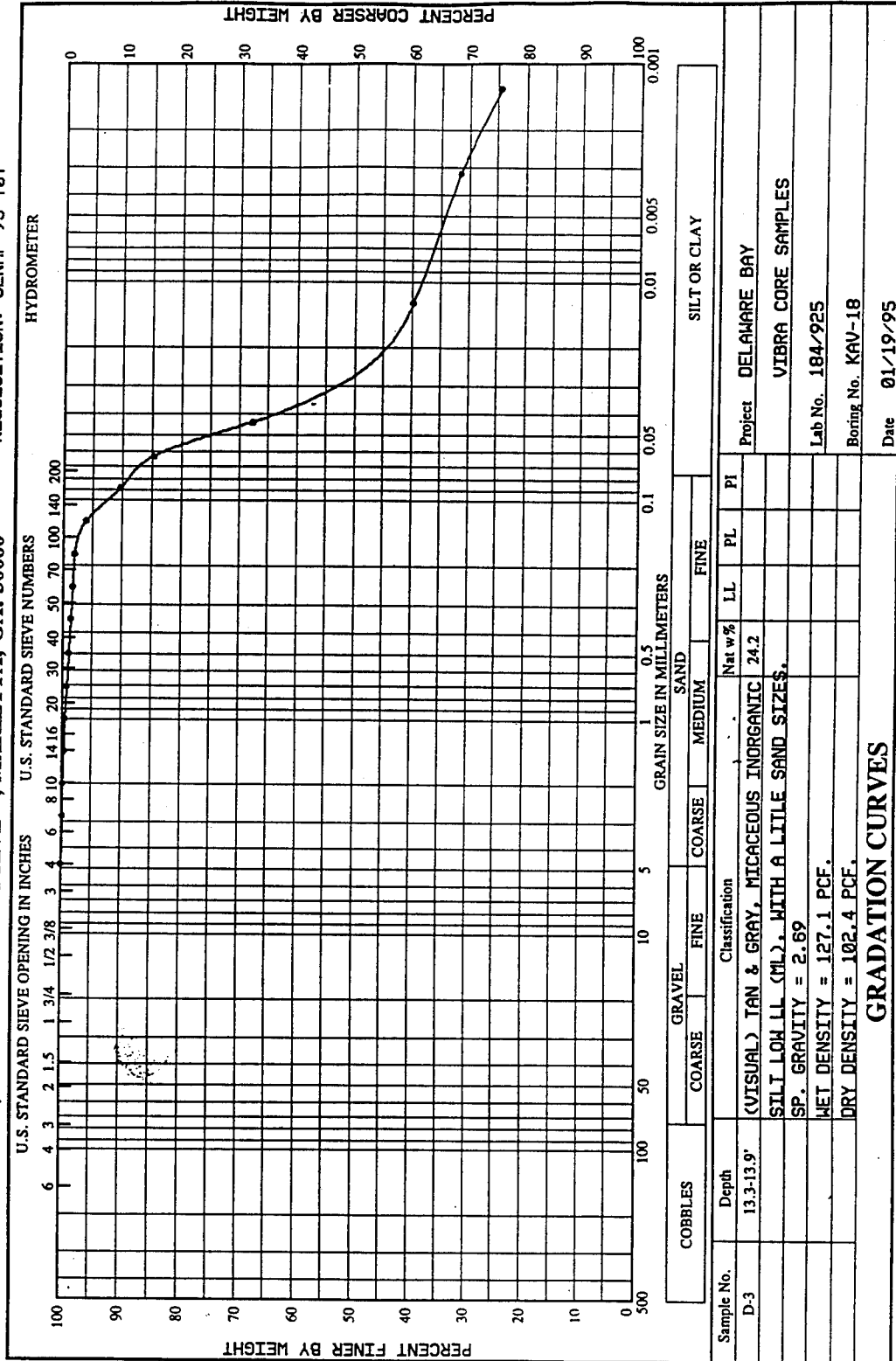
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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707



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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060



| | | | | |
|----------------------------------------------------------------|--|------------|---------------------------|--|
| Project: DELAWARE BAY | | | Boring No. KAV-19 | |
| Location: VIBRA CORE SAMPLES | | | Lab No. 184/926 | |
| Boring Depth (ft): 17.60 | | Elevation: | Work order: 7476 | |
| Datum/Notes: See grain size data on enclosed gradation curves. | | | Requisition: CENAP-95-707 | |

| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
|-----------------|-----------------|-------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------|
| | 1 | | | (Density Units = pcf) |
| | 2 | | TAN AND GRAY, POORLY GRADED SILTY SAND (SP-SM), WITH A LITTLE GRAVEL SIZES. | |
| | 3 | | ----- | SA D-1 2.3 - 2.9 WET DEN. = 129.1, DRY DEN = 114.0, MC = 13.3 %. |
| | 4 | | TANNISH GRAY, SILTY SAND (SM). | SA (A) 3.7 - 4.0' |
| | 5 | | ----- | |
| | 6 | | | |
| | 7 | | LT. GRAY AND TAN, SILTY SAND (SM), WITH A TRACE OF MICA. | |
| | 8 | | ----- | SA D-2 7.1 - 7.6' WET DEN. = 111.0, DRY DEN. = 93.7, MC = 18.5 %. |
| | 9 | | | SA (B) 8.6 - 8.9' |
| | 10 | | | |
| | 11 | | | |
| | 12 | | TAN AND TANNISH GRAY, SILTY SAND (SM), WITH A TRACE OF MICA. | |
| | 13 | | | SA D-3 12.5 - 13.0' WET DEN. = 120.4, DRY DEN = 99.0, MC = 21.6 %. |
| | 14 | | | SA (C) 13.7 - 14.0' |
| | 15 | | | |
| | 16 | | | |
| | 17 | | | SA D-4 16.0 - 16.5' WET DEN = 120.6, DRY DEN = 99.3, MC = 21.4 %. |
| | | | ----- | SA (D) 17.3 - 17.6' |

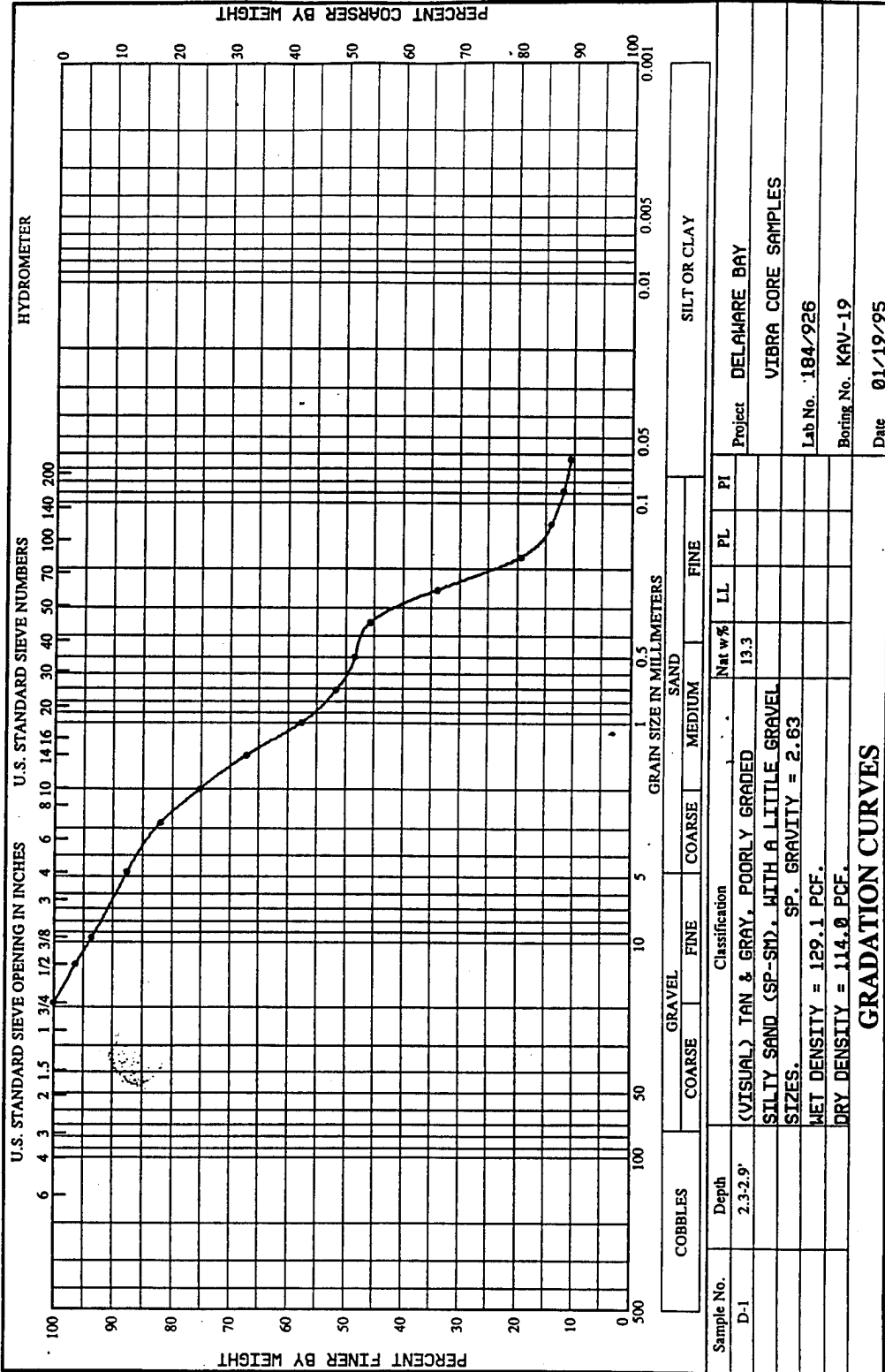
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LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

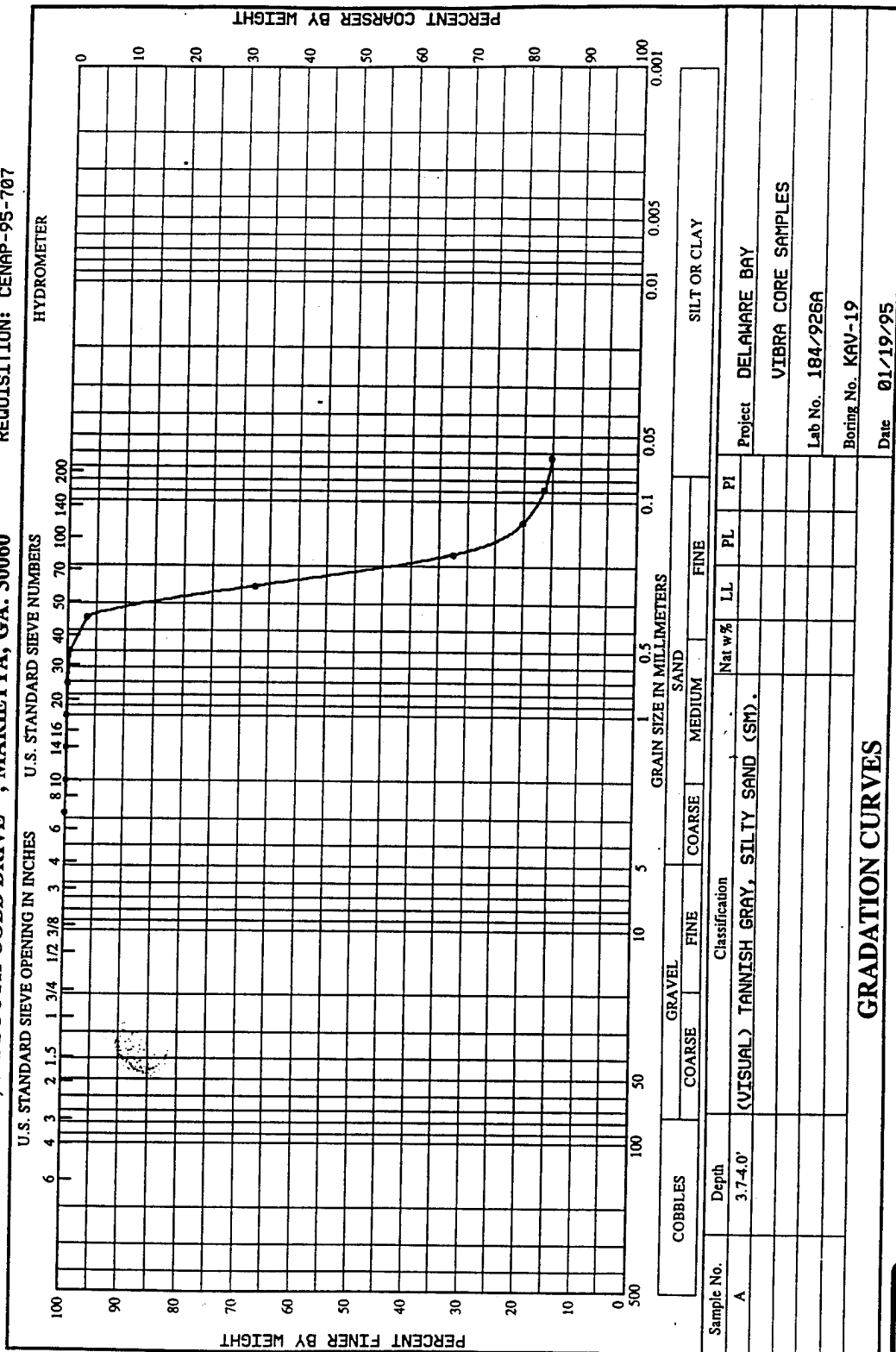
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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707

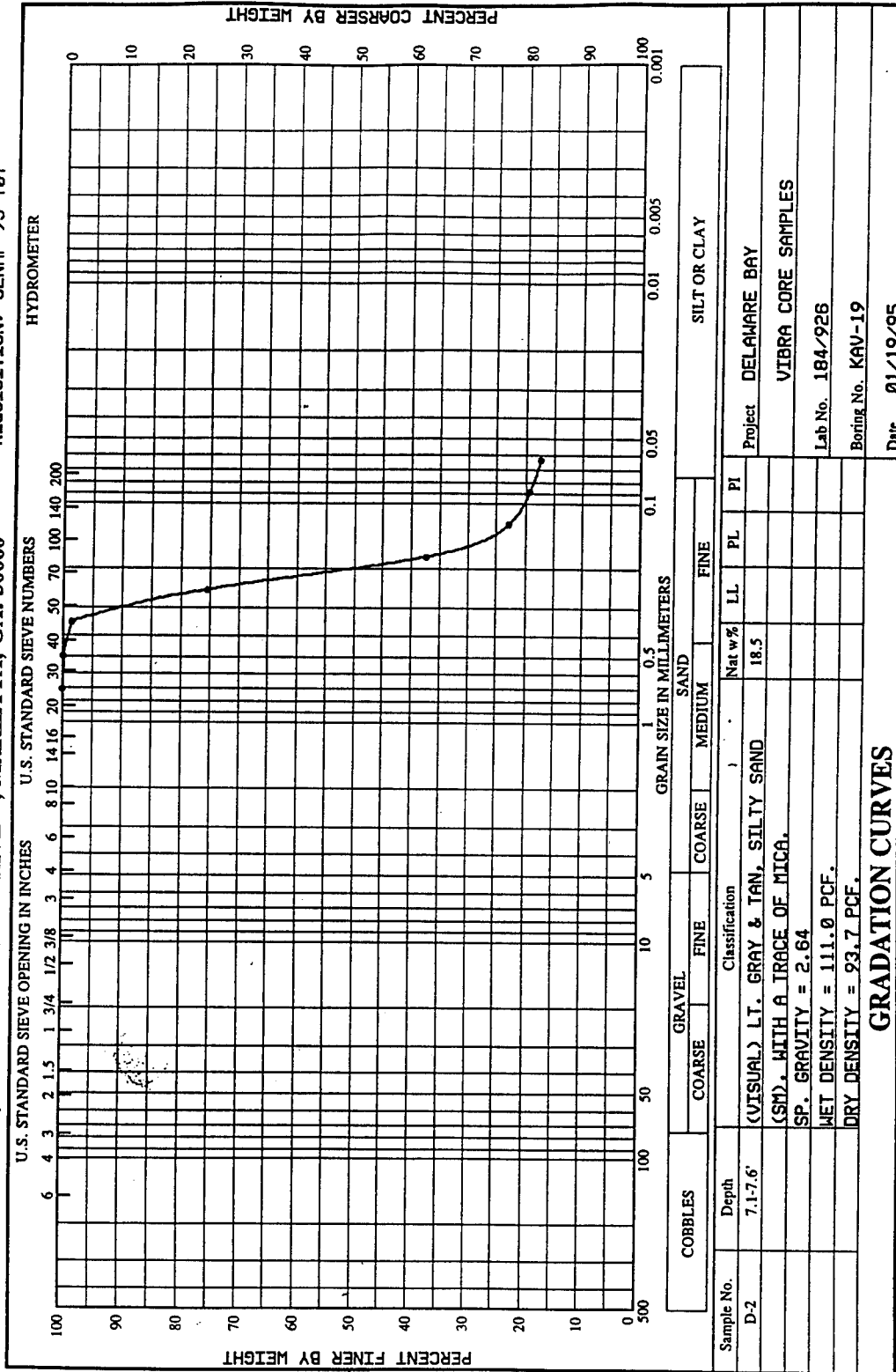


GRADATION CURVES

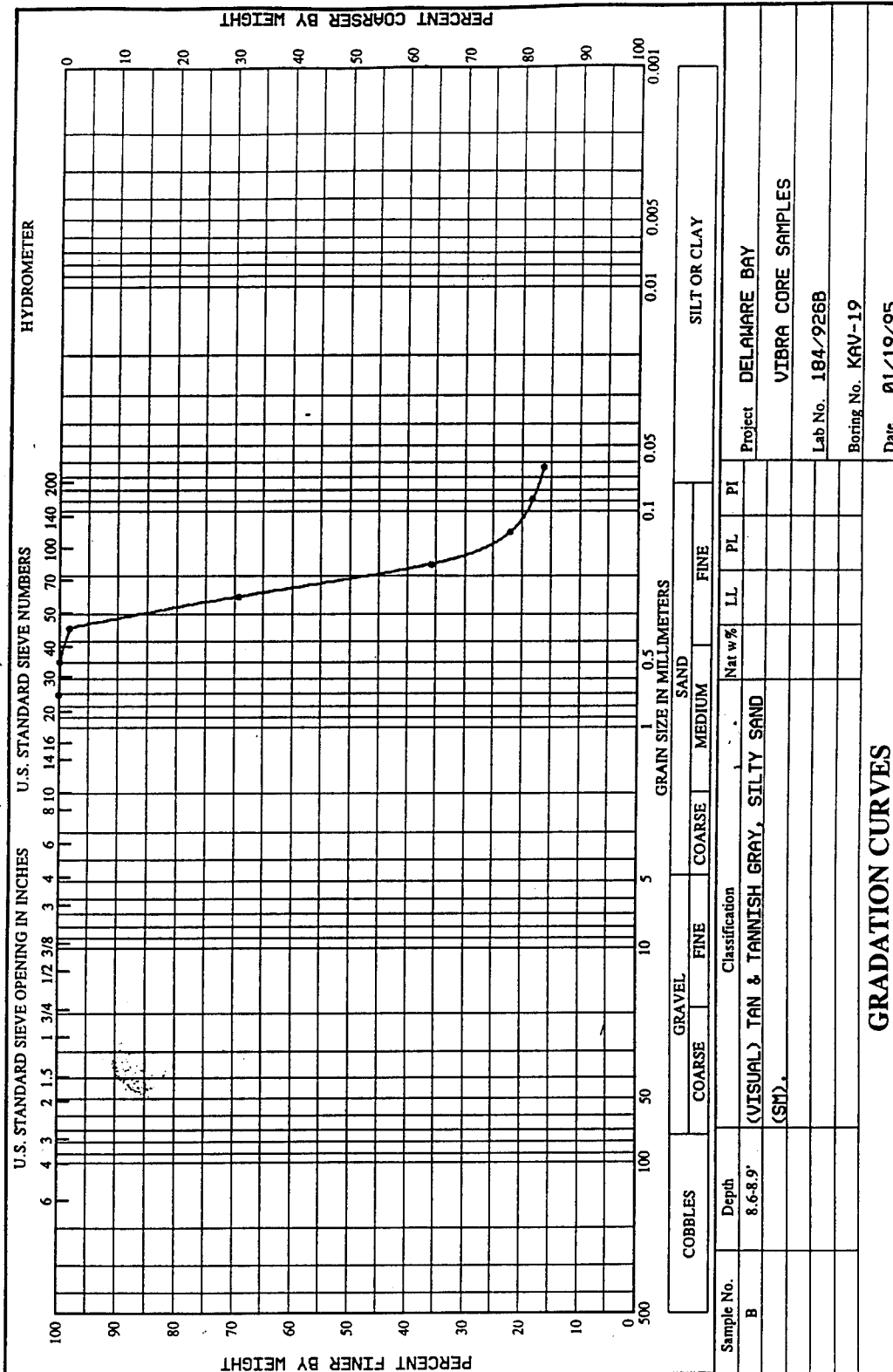
| GRAIN SIZE IN MILLIMETERS | | | | | | | | | | | | | 0.1 | 0.075 | 0.01 | 0.005 | 0.001 |
|---------------------------|----------|-----------------------------------------|------|--|--------|---------|------|----|--------------|--------------------|--|--|-----|-------|------|-------|-------|
| COBBLES | | GRAVEL | | | SAND | | | | SILT OR CLAY | | | | | | | | |
| | | COARSE | FINE | | COARSE | MEDIUM | FINE | | | | | | | | | | |
| Sample No. | Depth | Classification | | | | Nat w % | LL | PL | PI | Project | | | | | | | |
| A | 3.7-4.0' | (VISUAL) TANNISH GRAY, SILTY SAND (SM). | | | | | | | | DELAWARE BAY | | | | | | | |
| | | | | | | | | | | VTBRA CORE SAMPLES | | | | | | | |
| | | | | | | | | | | Lab No. 184/926A | | | | | | | |
| | | | | | | | | | | Boring No. KAV-19 | | | | | | | |
| GRADATION CURVES | | | | | | | | | | | | | | | | | |

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, Marietta, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707

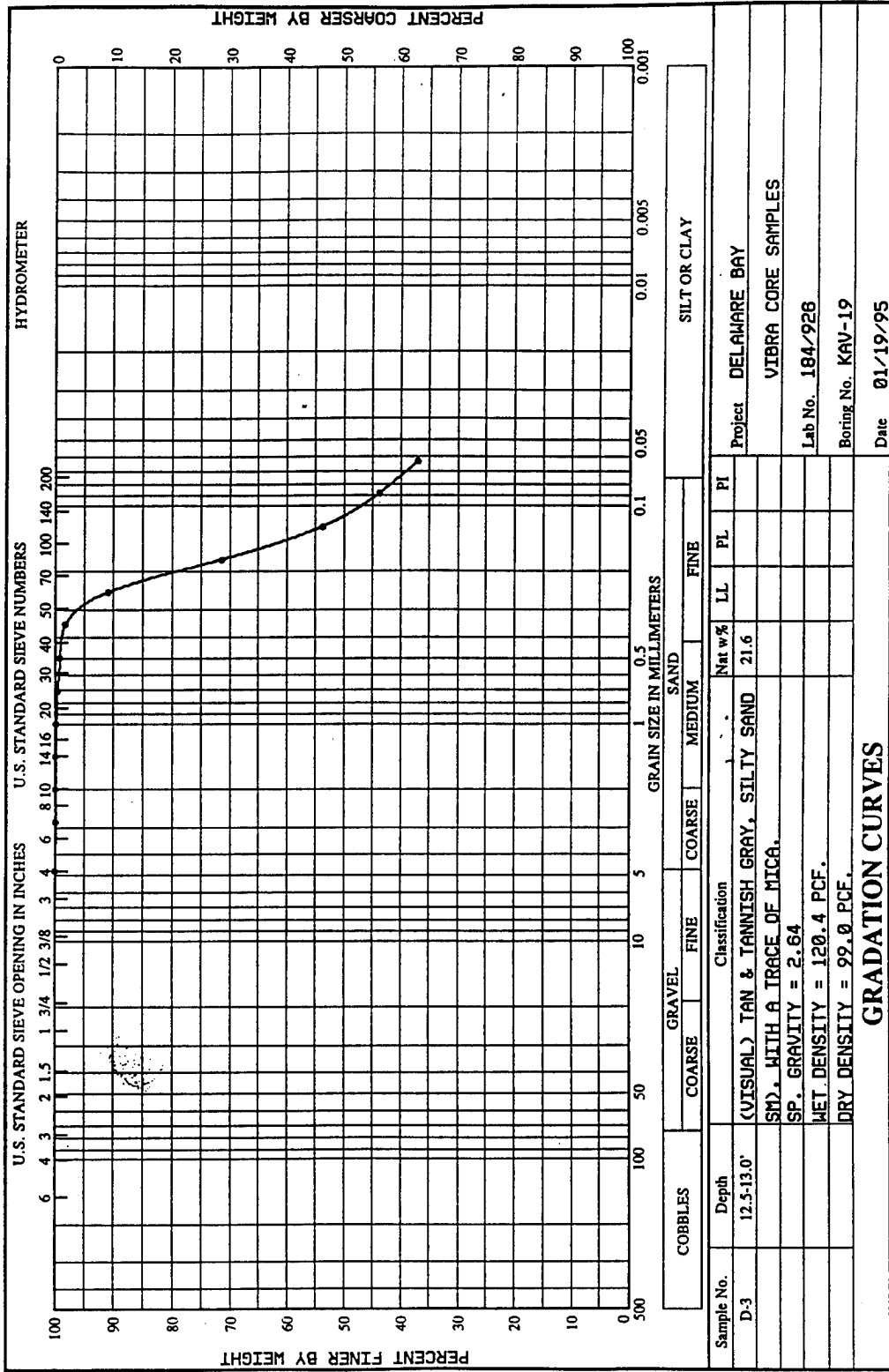


DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
 CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060
 WORK ORDER: 7476
 REQUISITION: CENAP-95-707



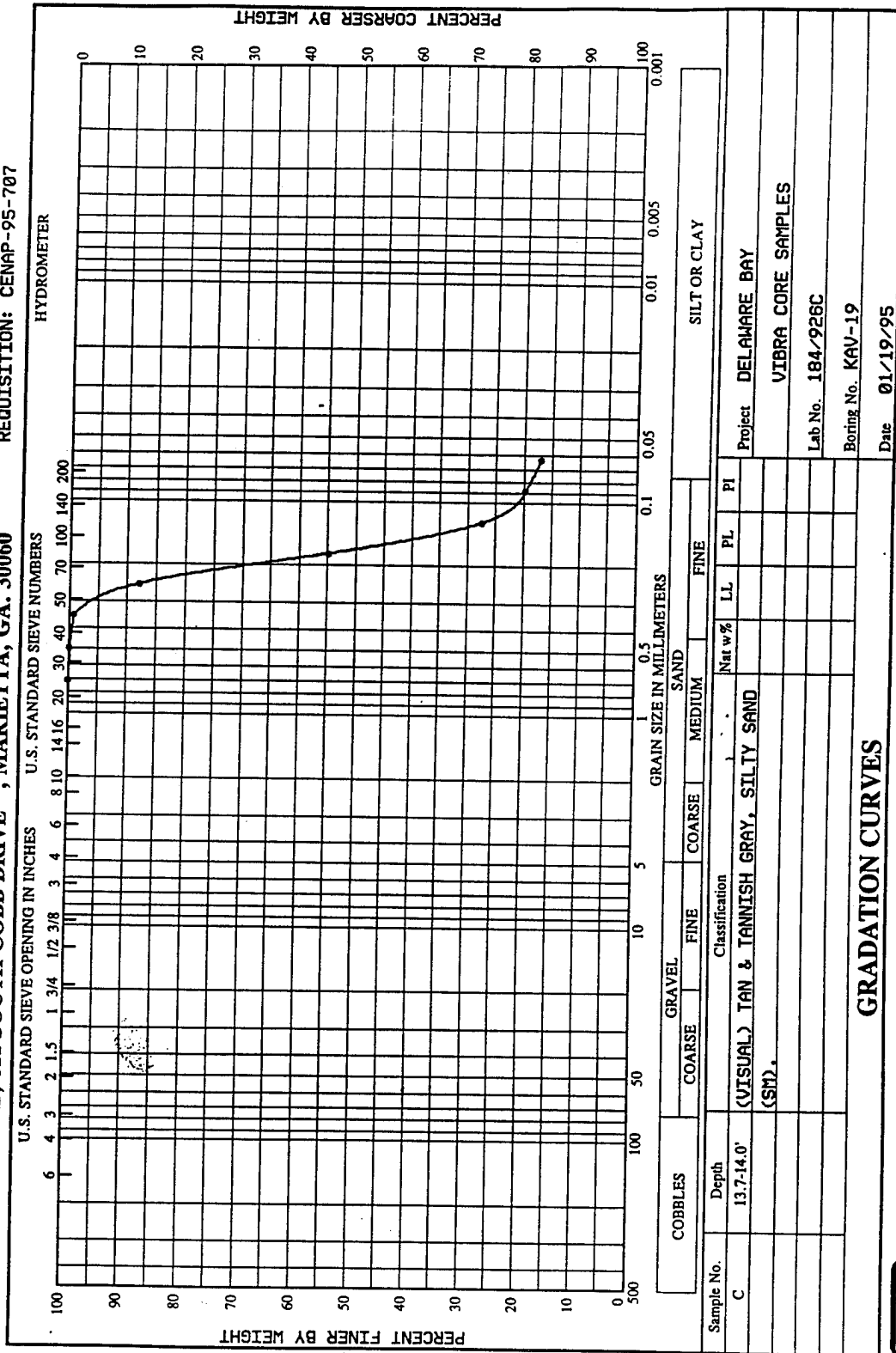
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
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WORK ORDER: 7476
REQUISITION: CENAP-95-707



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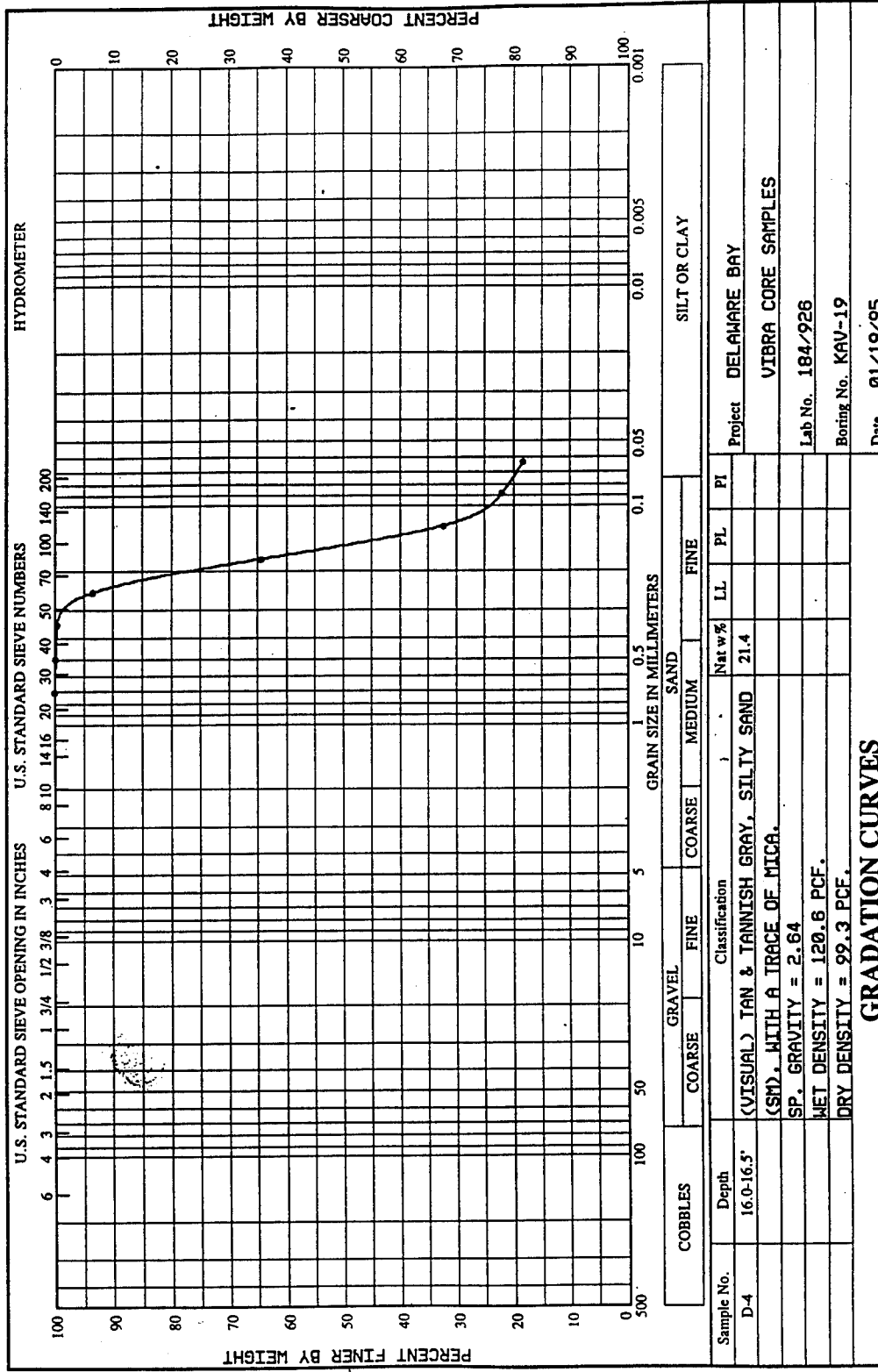
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REQUISITION: CENAP-95-707



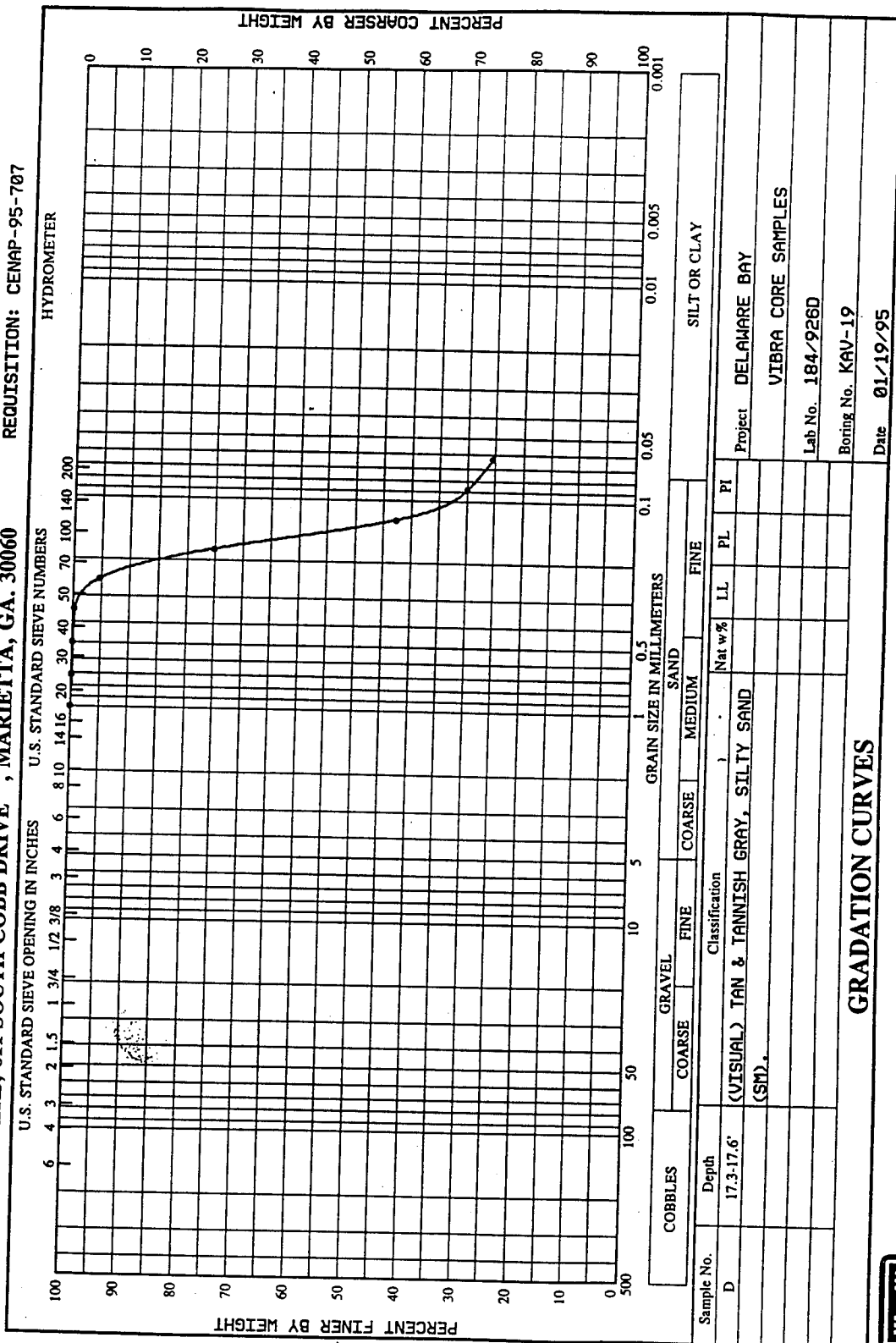
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
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WORK ORDER: 7476

REQUISITION: CENAP-95-707



WORK ORDER: 7476
REQUISITION: CENAP-95-707



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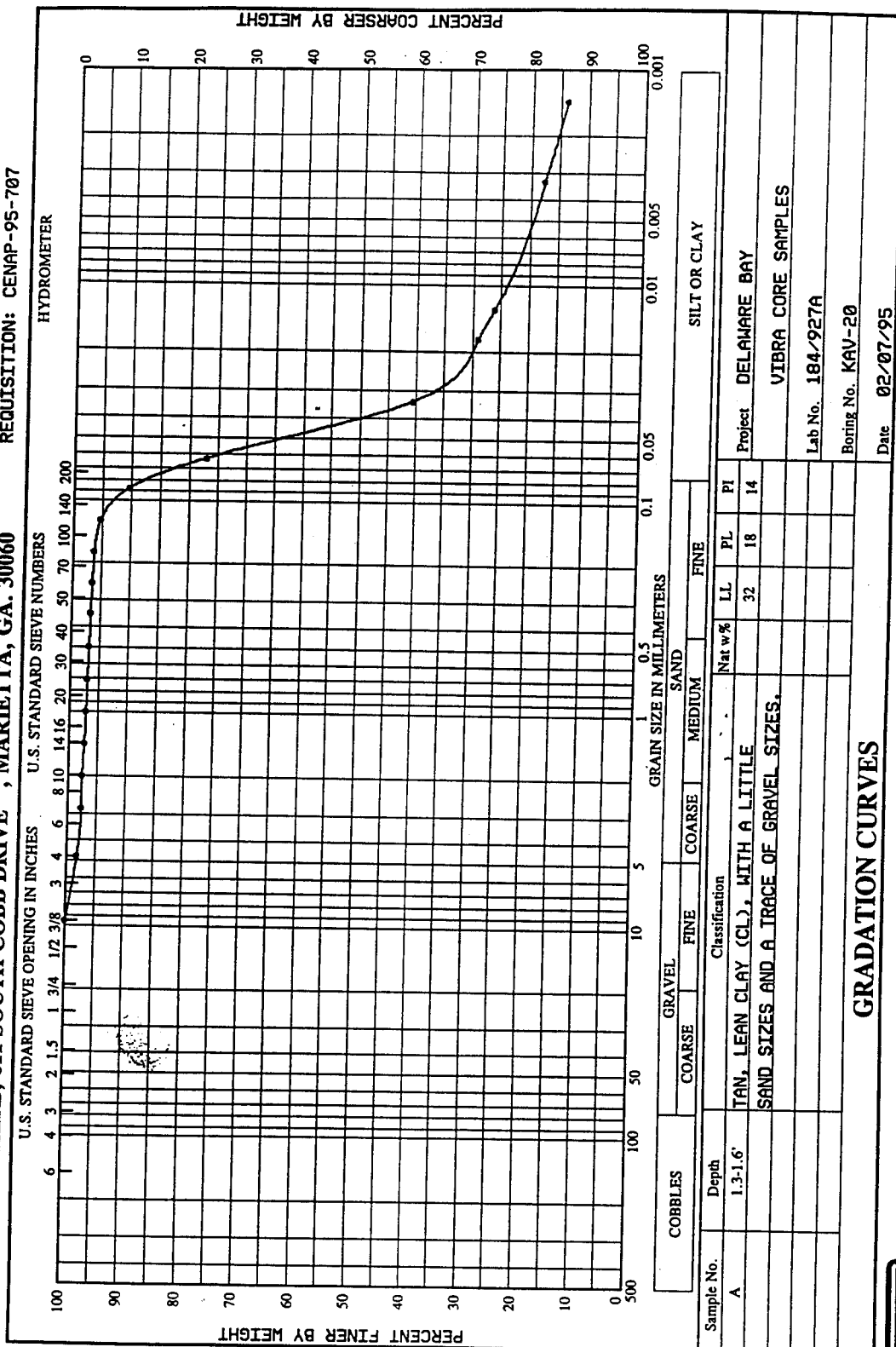
| Project: <i>DELAWARE BAY</i> | | | Boring No. <i>KAV-20</i> | |
|-----------------------------------------------------------------------|-----------------|-------------|----------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Location: <i>VIBRA CORE SAMPLES</i> | | | Lab No. <i>184/927</i> | |
| Boring Depth (ft): <i>16.00</i> | | Elevation: | Work order: <i>7476</i> | |
| Datum/Notes: <i>See grain size data on enclosed gradation curves.</i> | | | Requisition: <i>CENAP-95-707</i> | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | GRAY, GRAVELLY SILTY SAND (SM). | |
| | 2 | | TAN, LEAN CLAY (CL), WITH A LITTLE SAND SIZES AND A TRACE OF GRAVEL SIZES. | MA ATT (A) 1.3 - 1.6' |
| | 3 | | | MA D-1 2.5 - 3.0' WET DEN = 121.6, DRY DEN = 95.1, MC = 27.9 %. |
| | 4 | | TAN, LEAN CLAY (CL), WITH SOME SAND SIZES. | MA ATT (B) 4.0 - 4.3' |
| | 5 | | | |
| | 6 | | | |
| | 7 | | TAN, SANDY INORGANIC SILT LOW LL (ML). | |
| | 8 | | | MA D-2 7.3 - 7.8' WET DEN = 117.9, DRY DEN = 92.7, MC = 27.2 %. |
| | 9 | | | |
| | 10 | | | |
| | 11 | | | |
| | 12 | | | |
| | 13 | | | MA D-3 12.3 - 12.8' WET DEN = 119.3, DRY DEN = 96.1, MC = 24.2 %. |
| | 14 | | LT. GRAY, SILTY SAND (SM). | |
| | 15 | | | MA (C) 14.6 - 14.9' |
| | 16 | | | |
| | 17 | | | |

Date: 03/13/95

LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

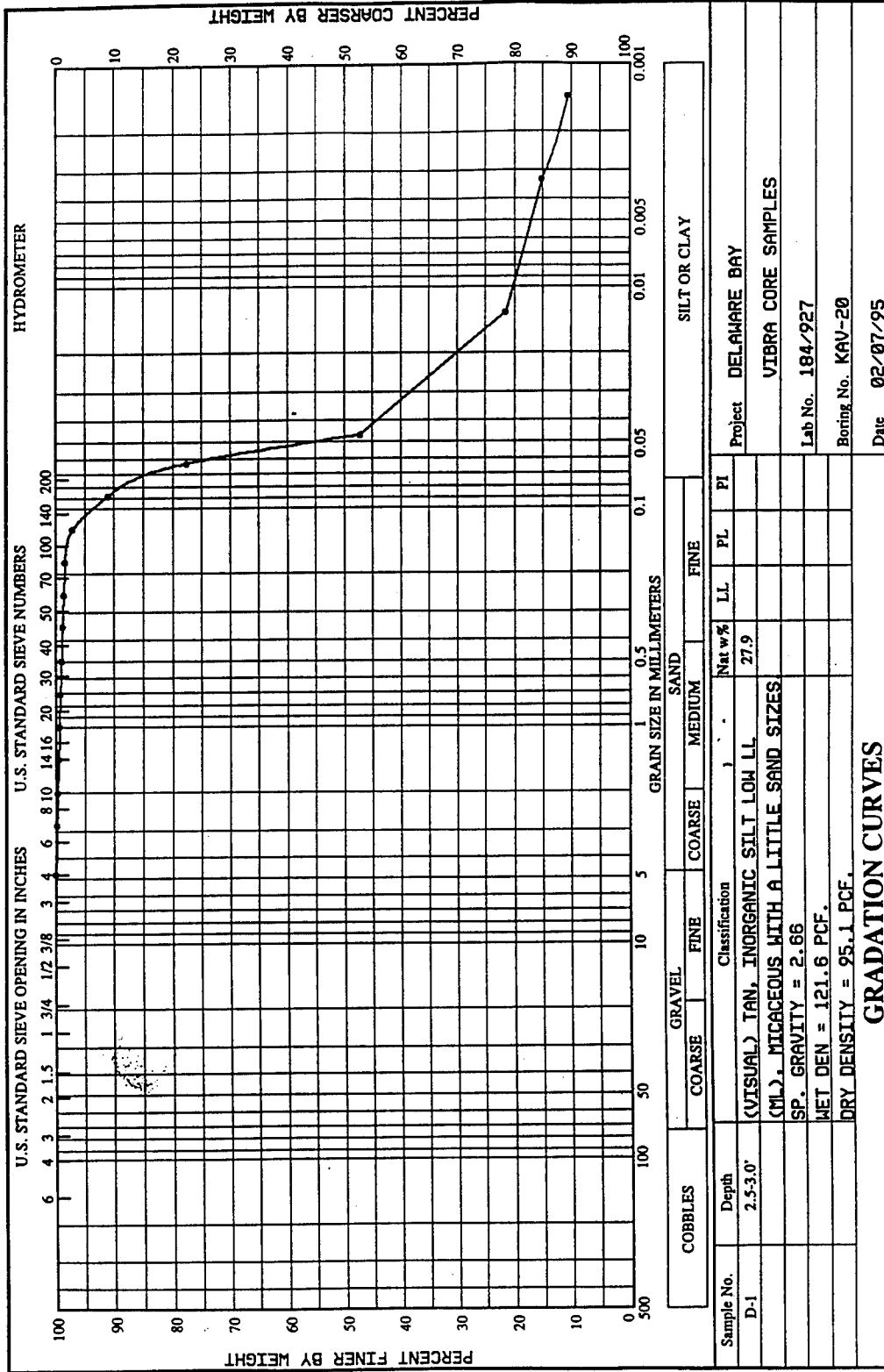
WORK ORDER: 7476
REQUISITION: CENAP-95-707



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 CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476

REQUISITION: CENAP-95-707

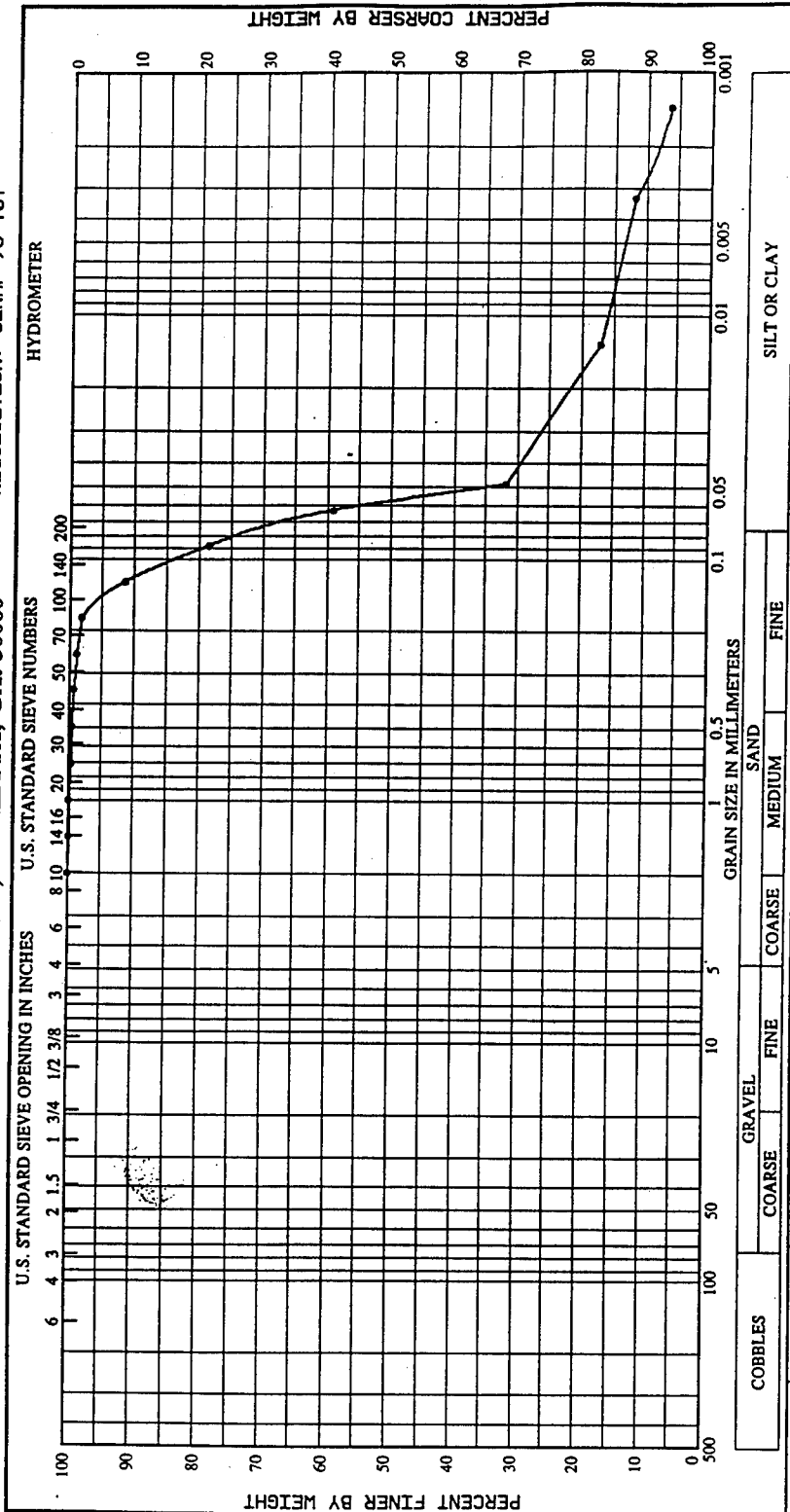


WORK ORDER: 7476
REQUISITION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707



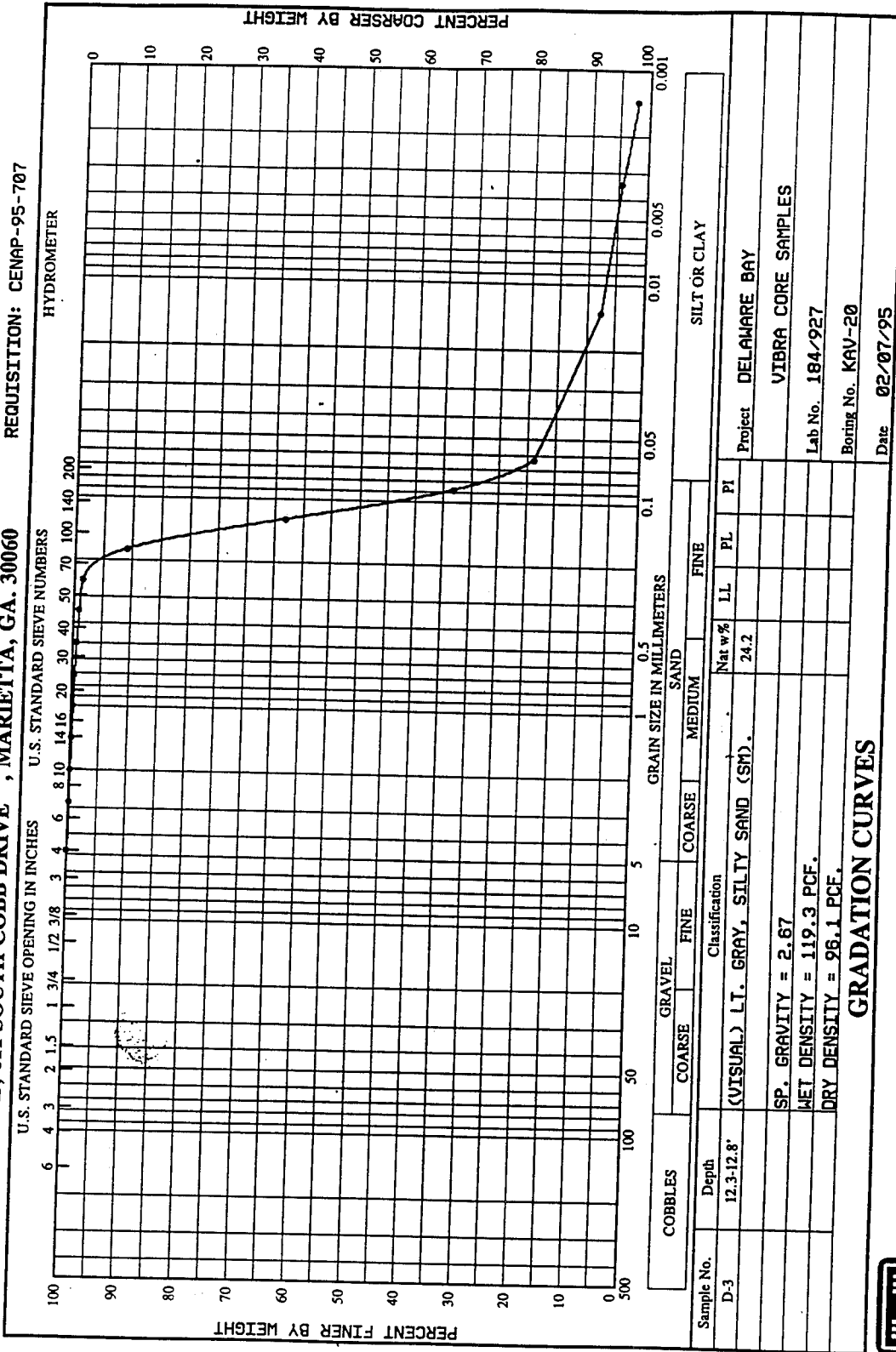
| | | | | | | | |
|------------|----------|----------------------------------------|---------|----|----|----|--------------------|
| Sample No. | Depth | Classification | Nat w % | LL | PL | PI | Project |
| D-2 | 7.3-7.8' | (VISUAL) TAN, MICACEOUS INORGANIC SILT | 27.2 | | | | DELAWARE BAY |
| | | LOW LL (ML), WITH SOME SAND SIZES. | | | | | VIBRA CORE SAMPLES |
| | | SP. GRAVITY = 2.67 | | | | | Lab No. 184/927 |
| | | WET DENSITY = 117.9 PCF. | | | | | Boring No. KAV-20 |
| | | DRY DENSITY = 92.7 PCF. | | | | | Date 03/13/95 |

GRADATION CURVES



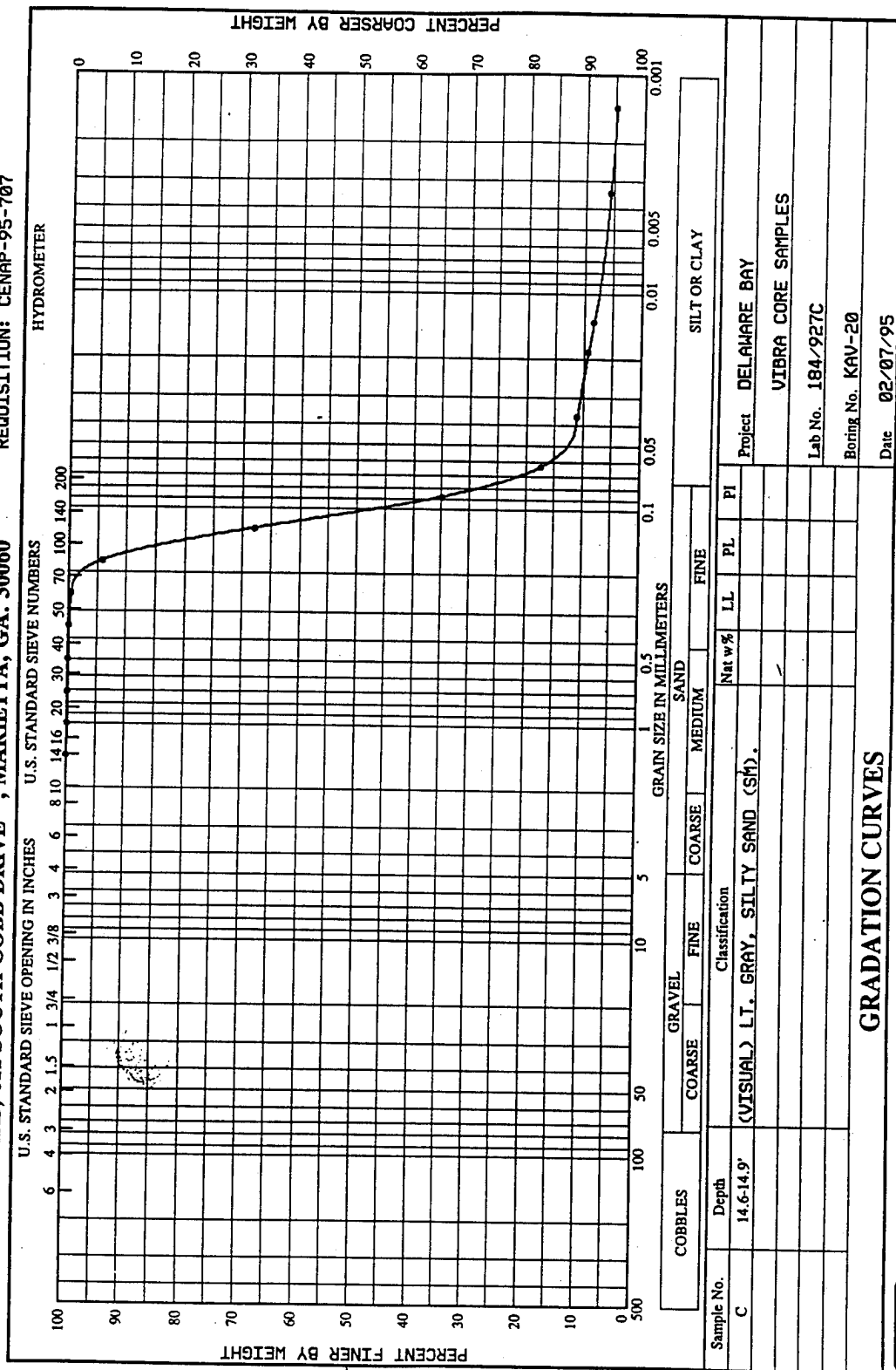
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707



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| | | | | |
|----------------------------------------------------------------|--|------------|---------------------------|--|
| Project: DELAWARE BAY | | | Boring No. KAV-21 | |
| Location: VIBRA CORE SAMPLES | | | Lab No. 184/928 | |
| Boring Depth (ft): 17.30 | | Elevation: | Work order: 7476 | |
| Datum/Notes: See grain size data on enclosed gradation curves. | | | Requisition: CENAP-95-707 | |

| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments (Density Units = pcf) |
|-----------------|-----------------|-------------|-----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| | 1 | | TAN, POORLY GRADED SAND (SP), WITH A TRACE OF MICA AND SHELL FRAGMENTS. | |
| | 2 | | | SA D-1 2.1 - 2.6' WET DEN = 114.5 DRY DEN = 106.5, MC = 7.5 %. |
| | 3 | | | |
| | 4 | | | SA (A) 4.0 - 4.3' |
| | 5 | | TAN AND LT. BROWN, POORLY GRADED SAND (SP). | |
| | 6 | | | SA (B) 5.6 - 5.9' |
| | 7 | | GRAY, SILTY SAND (SM). | |
| | 8 | | | SA D-2 7.0 - 7.5' WET DEN = 120.0 DRY DEN = 95.1, MC = 26.2 %. |
| | 9 | | GRAY, SILTY SAND (SM), WITH POCKETS AND LENSES OF POORLY GRADED SILTY SAND (SP-SM) AND OCCASIONAL POCKETS OF PLASTIC FINES. | MA (C) 8.2 - 8.5' |
| | 10 | | | |
| | 11 | | BROWNISH GRAY, SILTY SAND (SM), WITH SOME GRAVEL SIZES AND A TRACE OF SHELL FRAGMENTS. | |
| | 12 | | | SA (D) 11.3 - 11.6' |
| | 13 | | | SA D-3 12.6 - 13.1' WET DEN = 124.1, DRY DEN = 103.1, MC = 20.4 %. |
| | 14 | | | |
| | 15 | | TAN, POORLY GRADED SILTY SAND (SP-SM). | |
| | 16 | | | SA (E) 16.0 - 16.3' |
| | 17 | | | |

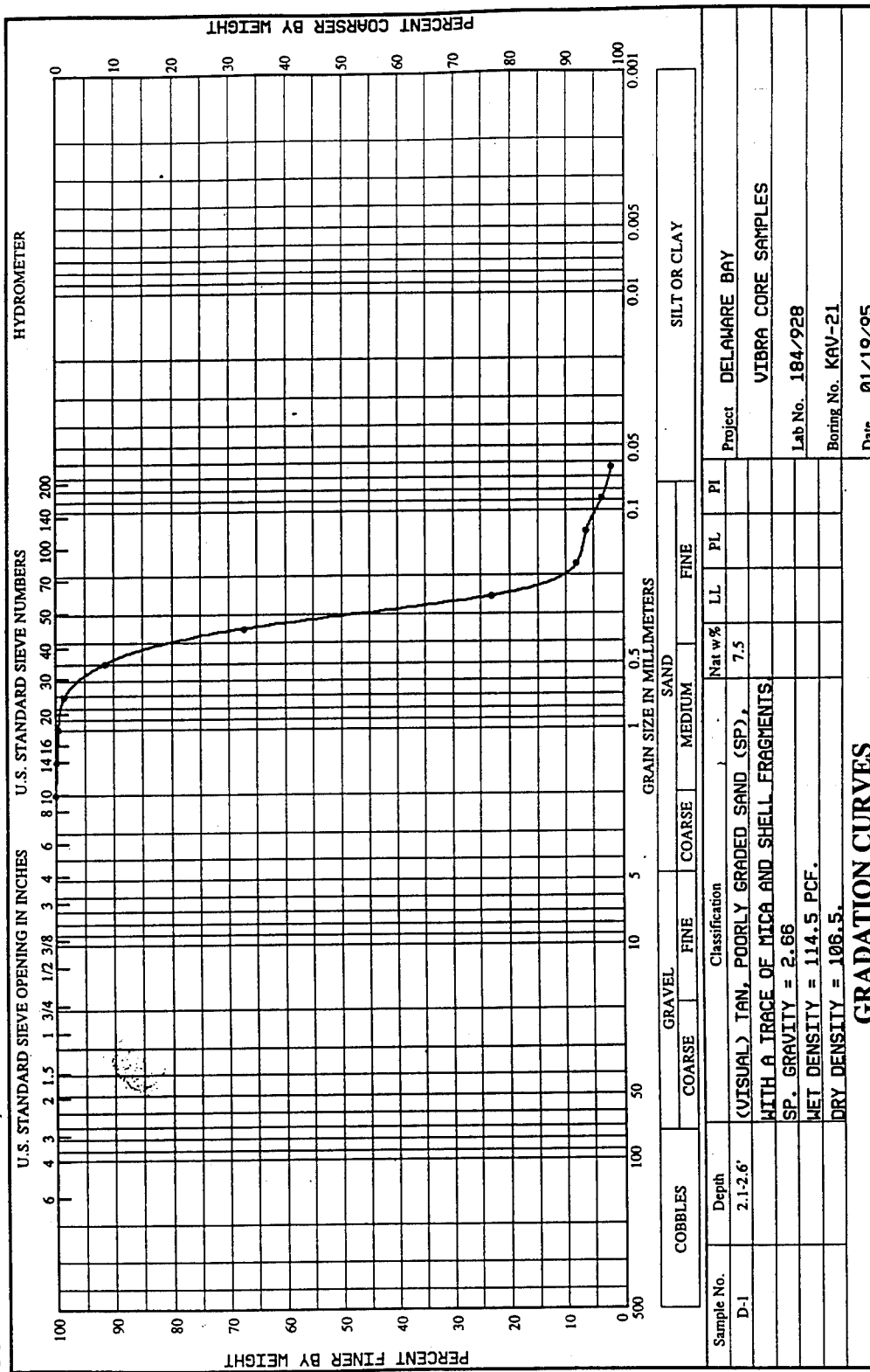
Date: 01/25/95

LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

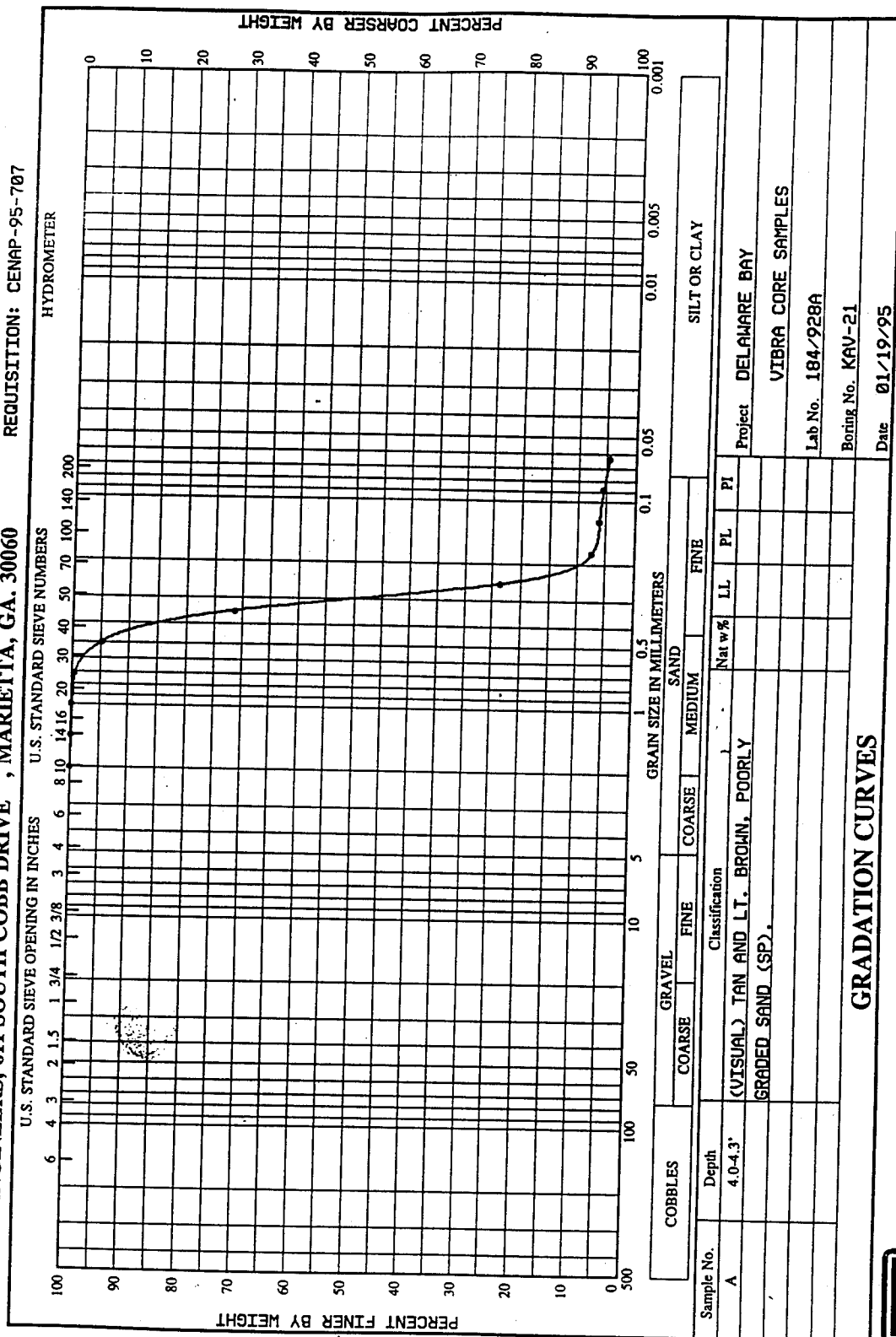
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707

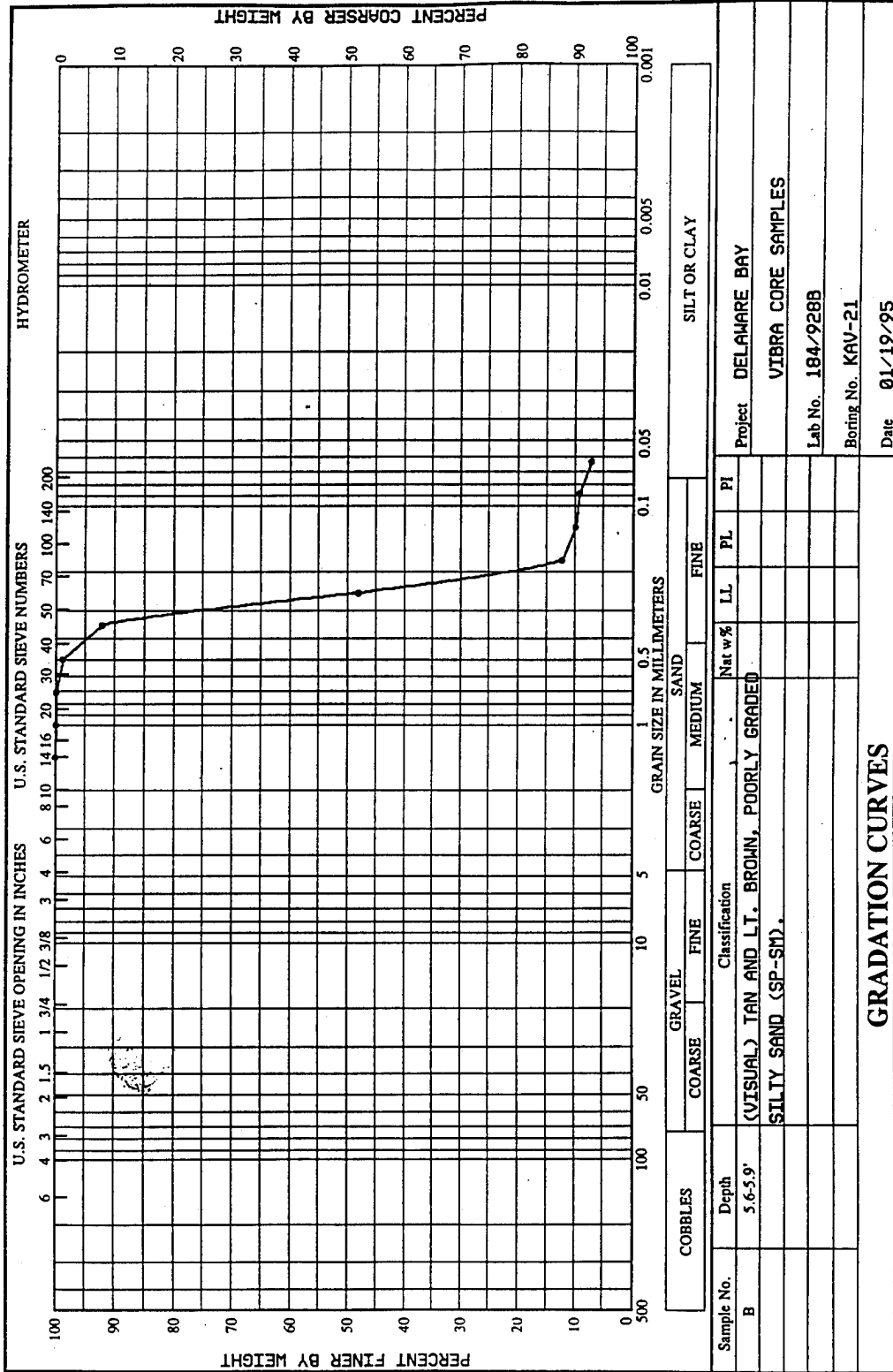


GRADATION CURVES



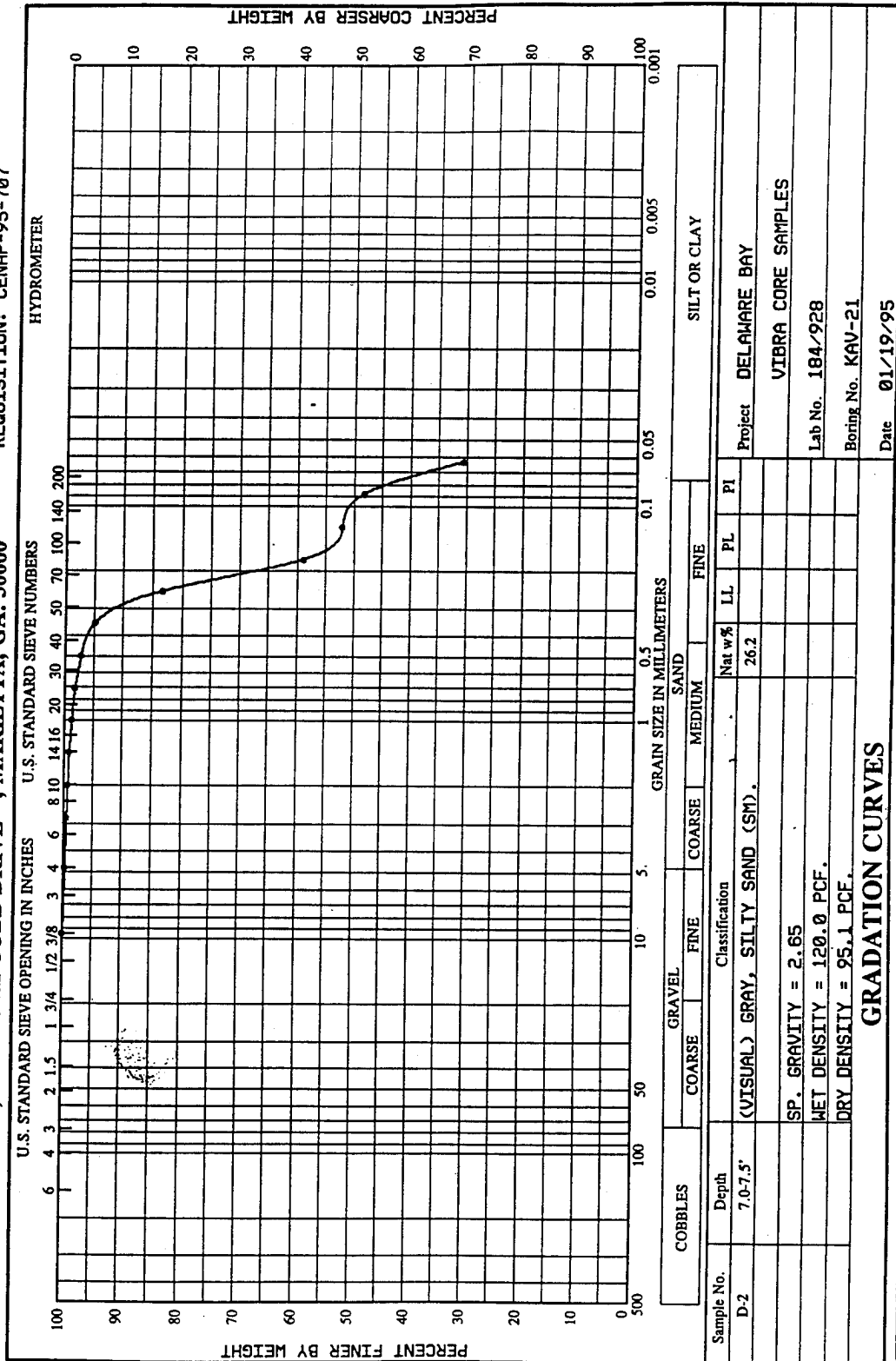
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707

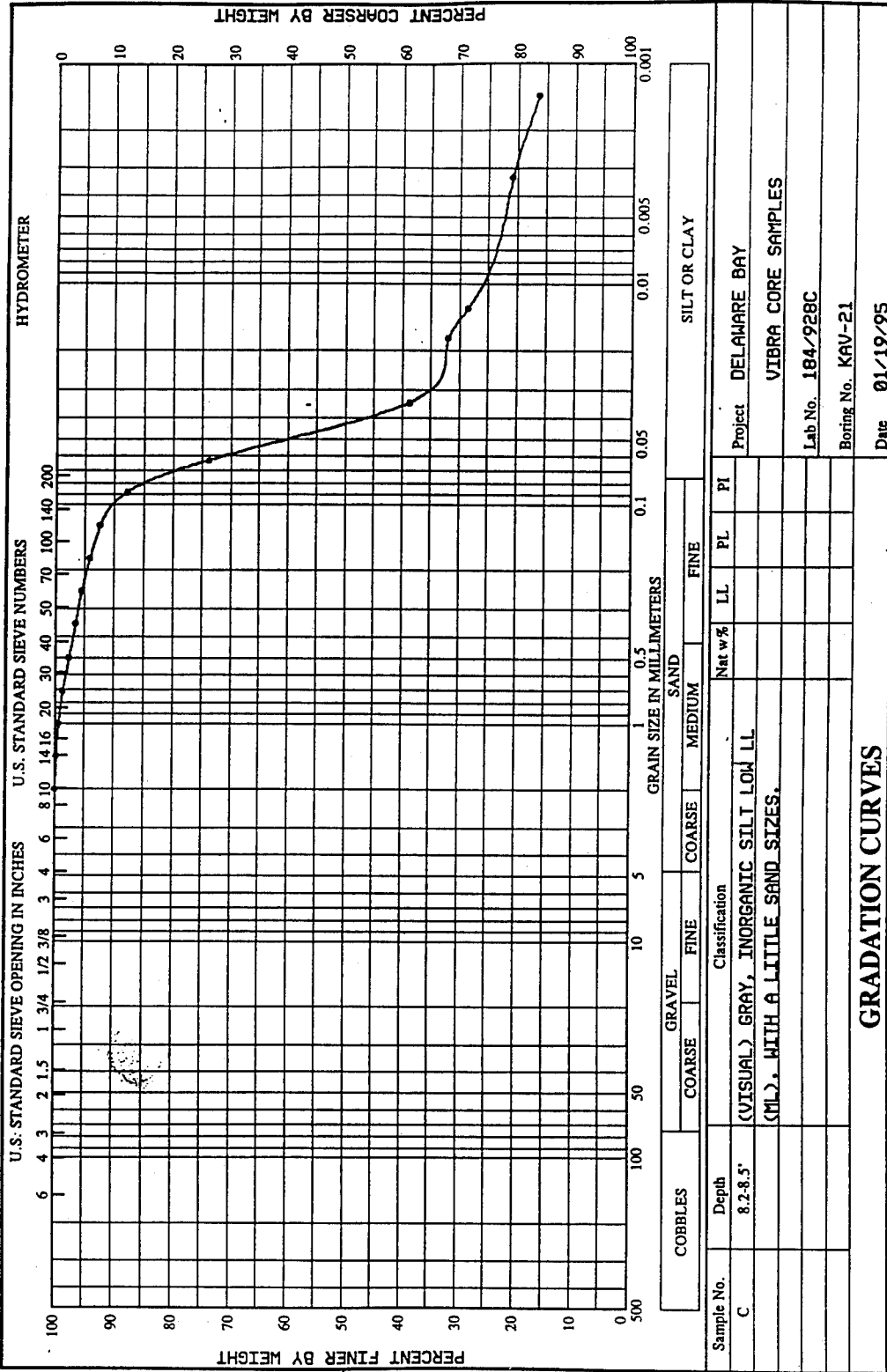


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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, Marietta, GA. 30060

WORK ORDER: 7478
REQUISITION: CENAP-95-707

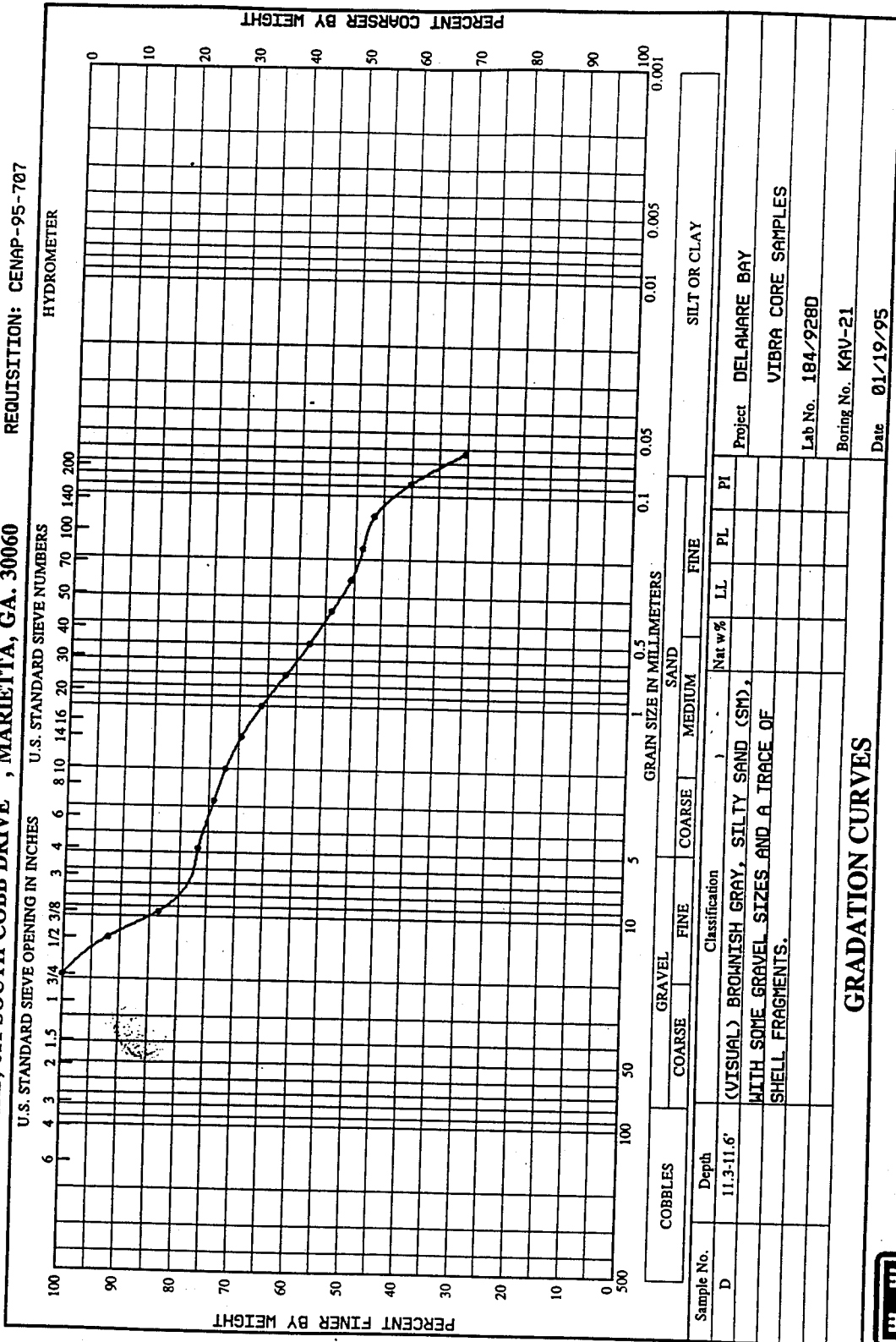


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 CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, Marietta, GA. 30060
 WORK ORDER: 7476
 REQUISITION: CENAP-95-787



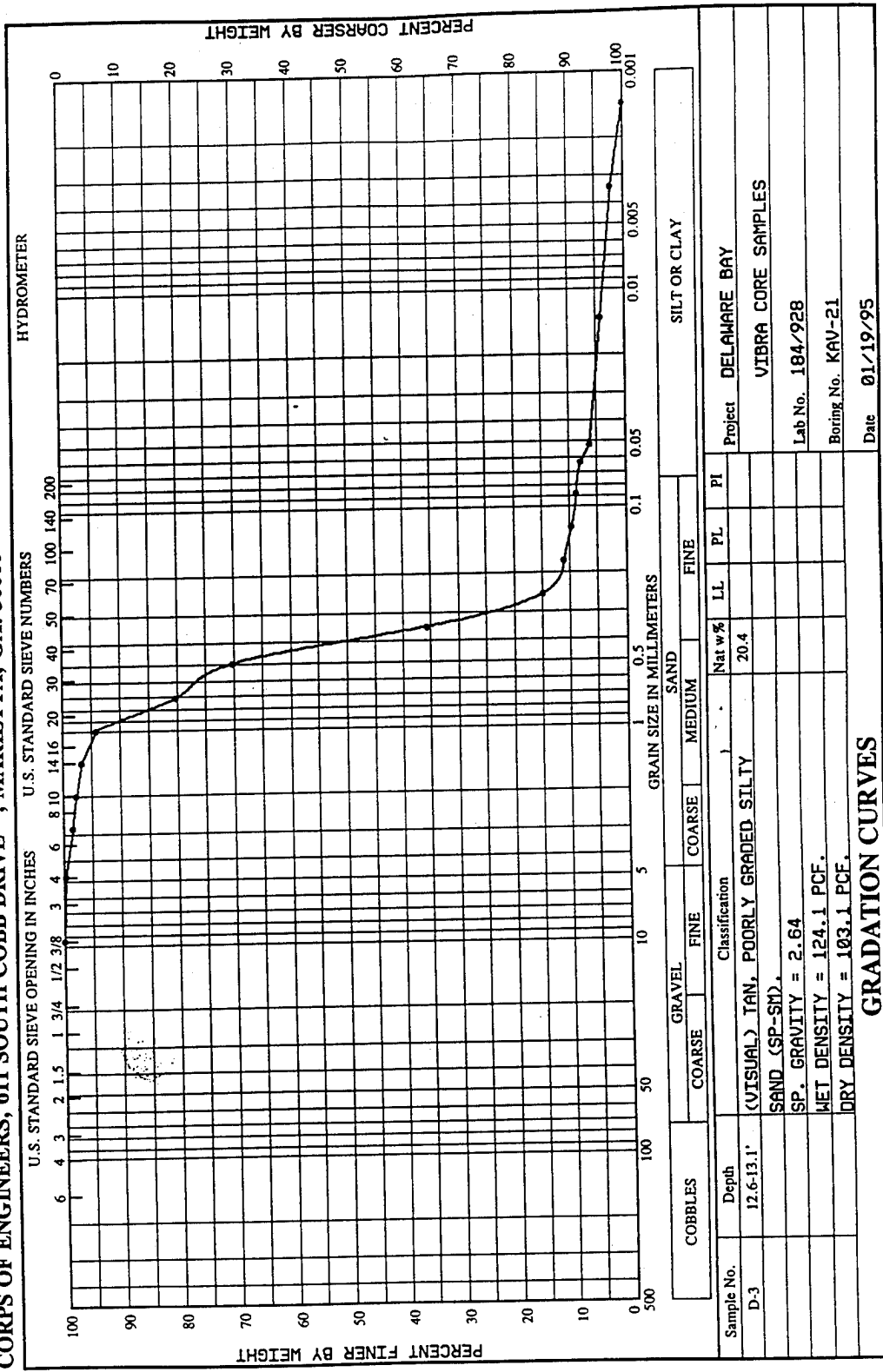
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



WORK ORDER: 7476
 REQUISITION: CENAP-95-707

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 CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060



WORK ORDER: 7476
REQUISITION: CENAP-95-707



DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060



| Project: DELAWARE BAY | | | Boring No. KAV-22 | |
|----------------------------------------------------------------|-----------------|-------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| Location: VIBRA CORE SAMPLES | | | Lab No. 184/929 | |
| Boring Depth (ft): 10.20 | | Elevation: | Work order: 7476 | |
| Datum/Notes: See grain size data on enclosed gradation curves. | | | Requisition: CENAP-95-707 | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | | | | (Density Units = pcf) |
| | 1 | | RUN # 2 | MA (A) 0.9 - 1.2' |
| | 2 | | TAN AND BROWNISH GRAY, SILTY SAND (SM), WITH PLASTIC FINES. | |
| | 3 | | ----- | SA D-1 2.2 - 2.7' WET DEN = 118.5, DRY DEN = 95.1, MC = 24.6 %. |
| | 4 | | GRAY, SANDY INORGANIC SILT LOW LL (ML). ----- | MA (B) 3.8 - 4.1' |
| | 5 | | | |
| | 6 | | LT. GRAY, SILTY SAND (SM). | SA (C) 6.0 - 6.3' |
| | 7 | | | |
| | 8 | | ----- | |
| | 9 | | | MA D-2 8.2 - 8.6' WET DEN = 106.2, DRY DEN = 67.7, MC = 56.8 %. |
| | 10 | | GRAY, INORGANIC SILT HIGH LL (MH), WITH A LITTLE SAND SIZES AND A TRACE OF MICA. ----- | |
| | 11 | | | |
| | 12 | | | |
| | 13 | | | |
| | 14 | | | |
| | 15 | | | |

Date: 01/20/95

LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060



| Project: DELAWARE BAY | | | Boring No. KAV-22 | |
|----------------------------------------------------------------|-----------------|-------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Location: VIBRA CORE SAMPLES | | | Lab No. 184/929 | |
| Boring Depth (ft): 15.20 | | Elevation: | | Work order: 7476 |
| Datum/Notes: See grain size data on enclosed gradation curves. | | | Requisition: CENAP-95-707 | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | RUN # 1 | (Density Units = pcf) |
| | 2 | | | |
| | 3 | | | |
| | 4 | | | |
| | 5 | | | |
| | 6 | | | |
| | 7 | | | |
| | 8 | | | SA D-3 7.0 - 7.5' WET DEN = 128.3 DRY DEN = 113.2, MC = 13.3 %. |
| | 9 | | TAN, POORLY GRADED SILTY SAND (SP-SM), WITH A TRACE OF GRAVEL SIZES. | SA (D) 9.0 - 9.3' |
| | 10 | | | |
| | 11 | | | |
| | 12 | | | |
| | 13 | | | |
| | 14 | | | SA D-4 13.5 - 14.0' WET DEN = 119.7, DRY DEN = 112.0, MC = 6.9 %. |
| | 15 | | TAN, POORLY GRADED SAND (SP), WITH SOME GRAVEL SIZES. | |

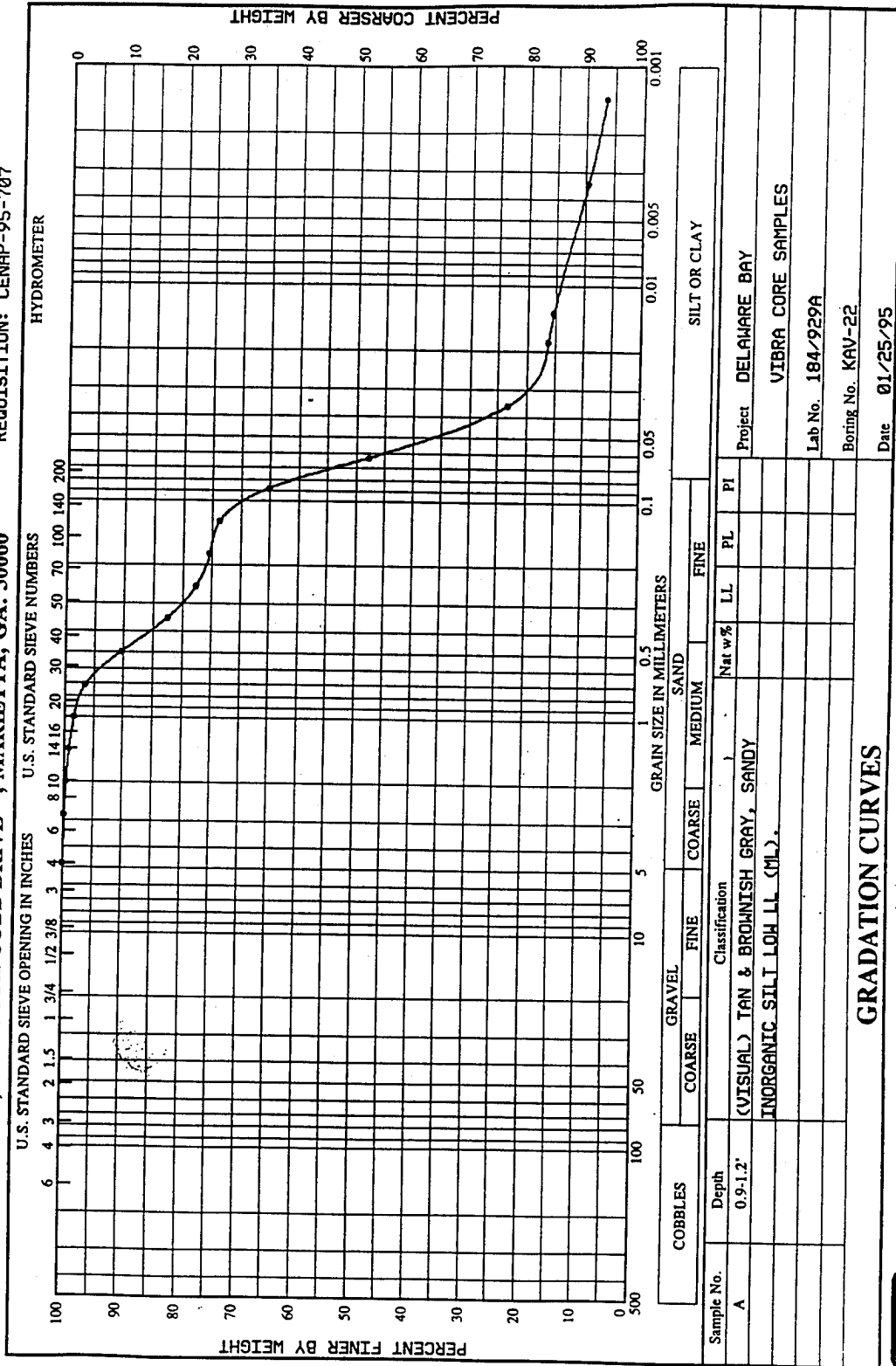
Date: 01/20/95

LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

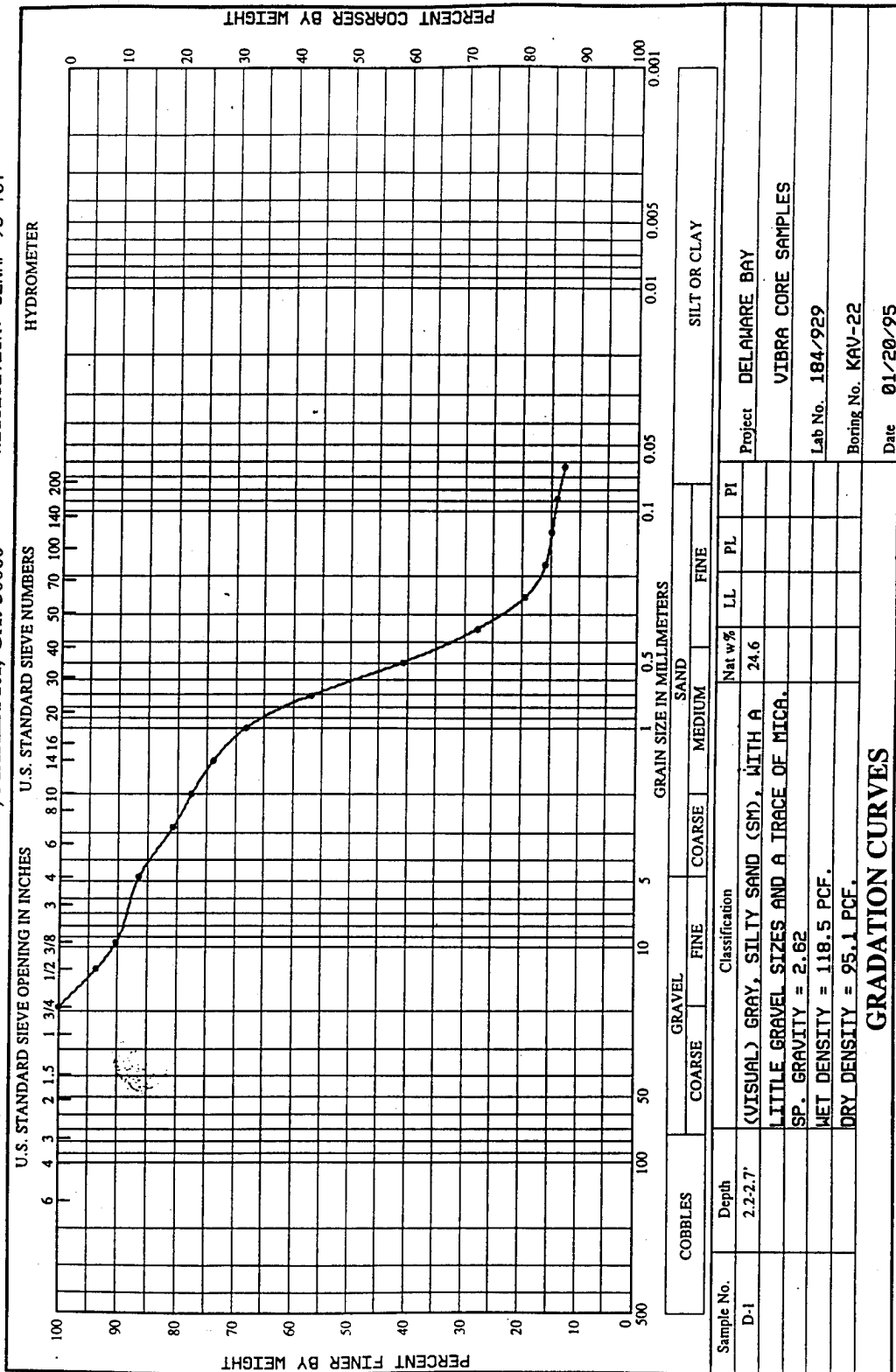
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



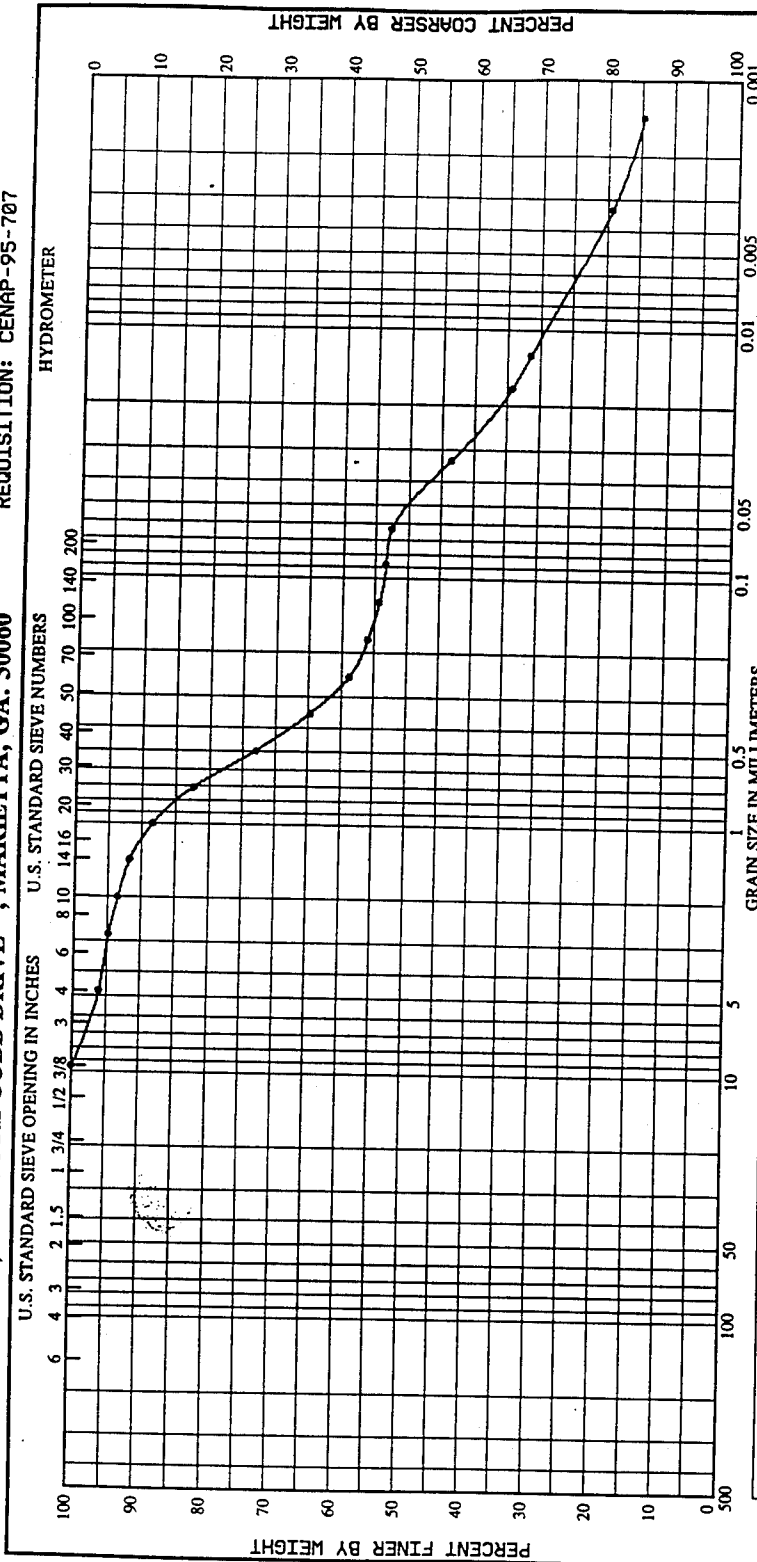
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707

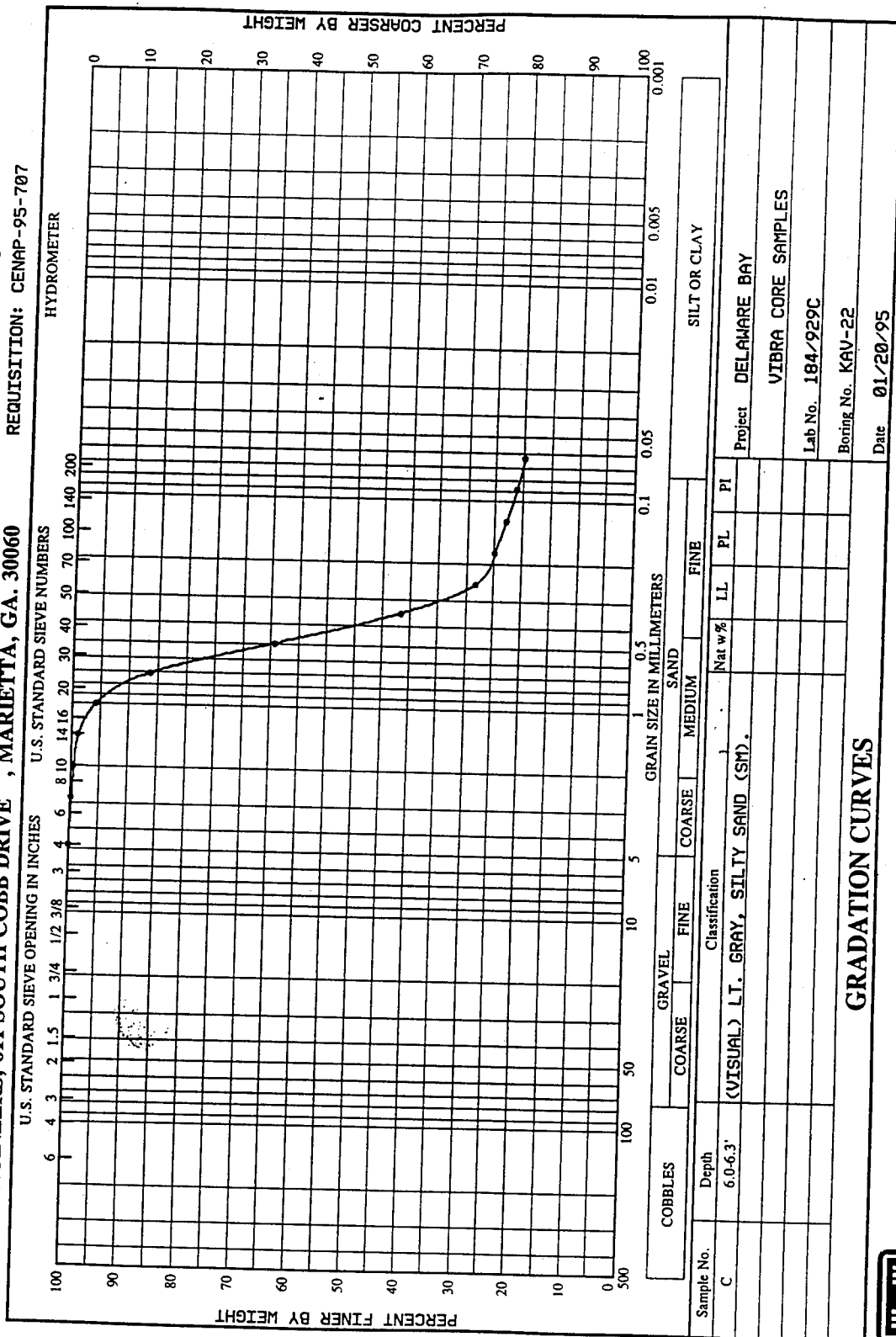


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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

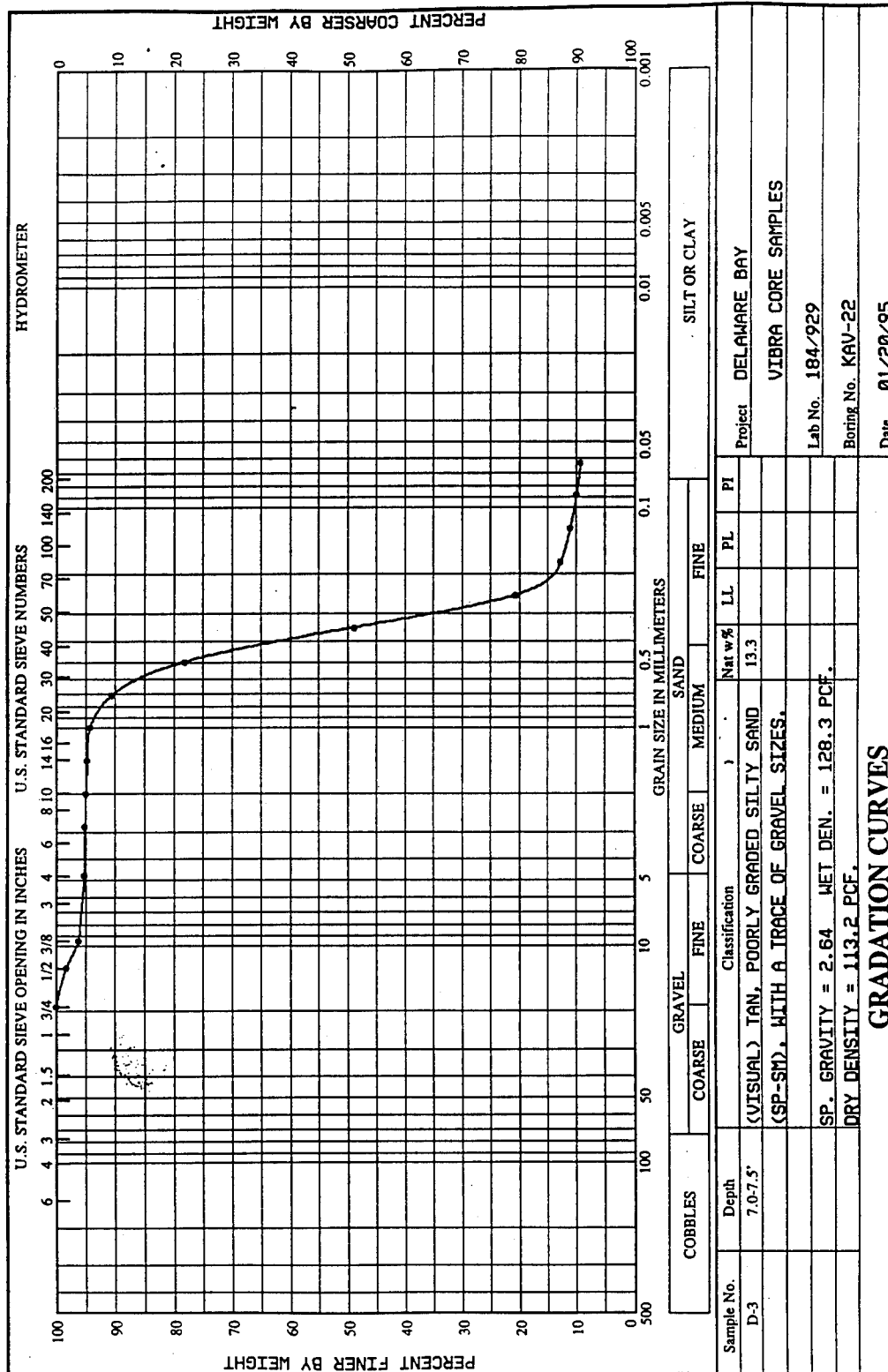
WORK ORDER: 7476
REQUISITION: CENAP-95-707



WORK ORDER: 7476
REQUISITION: CENAP-95-707

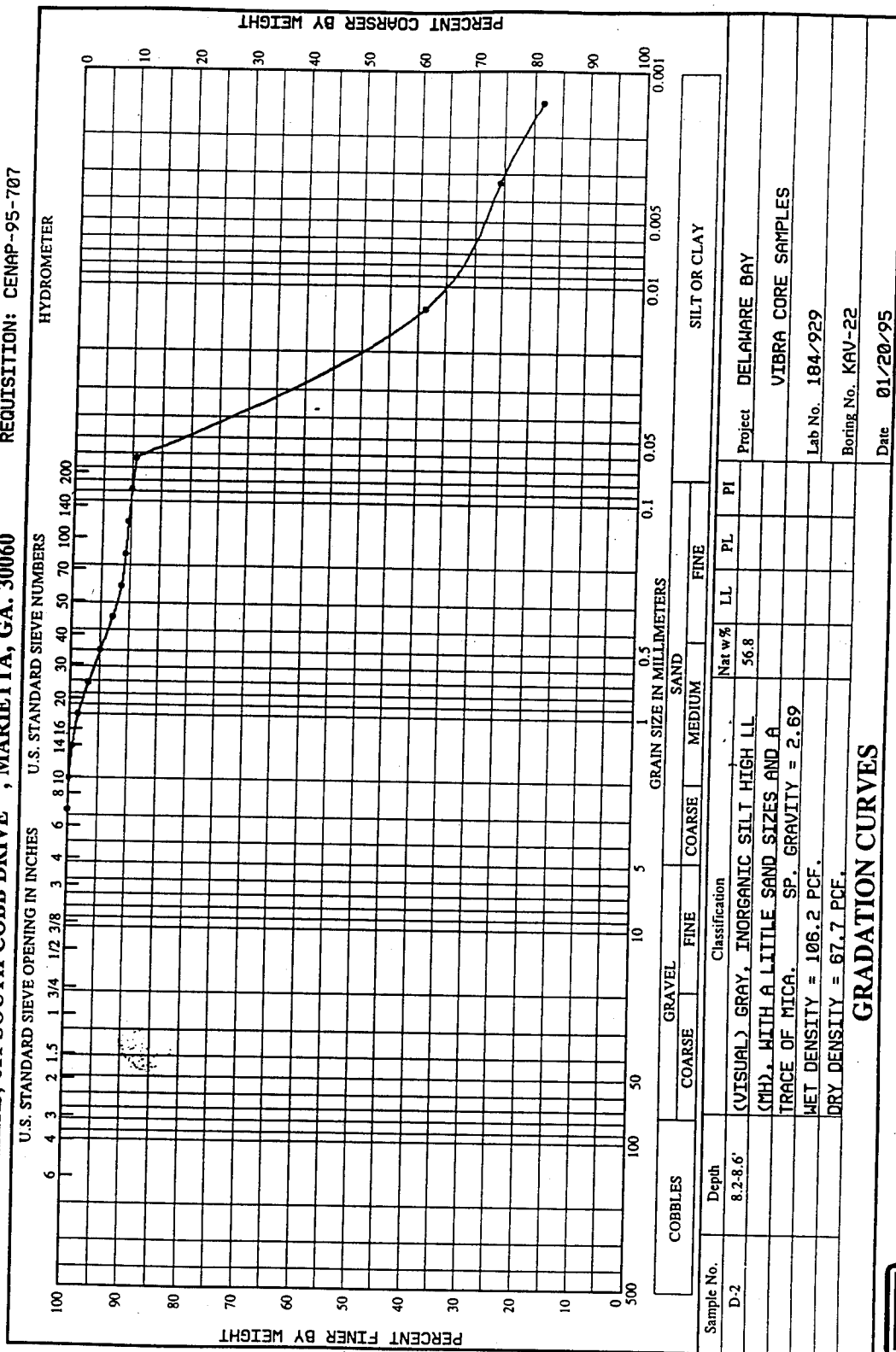


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REQUISITION: CENAP-95-707



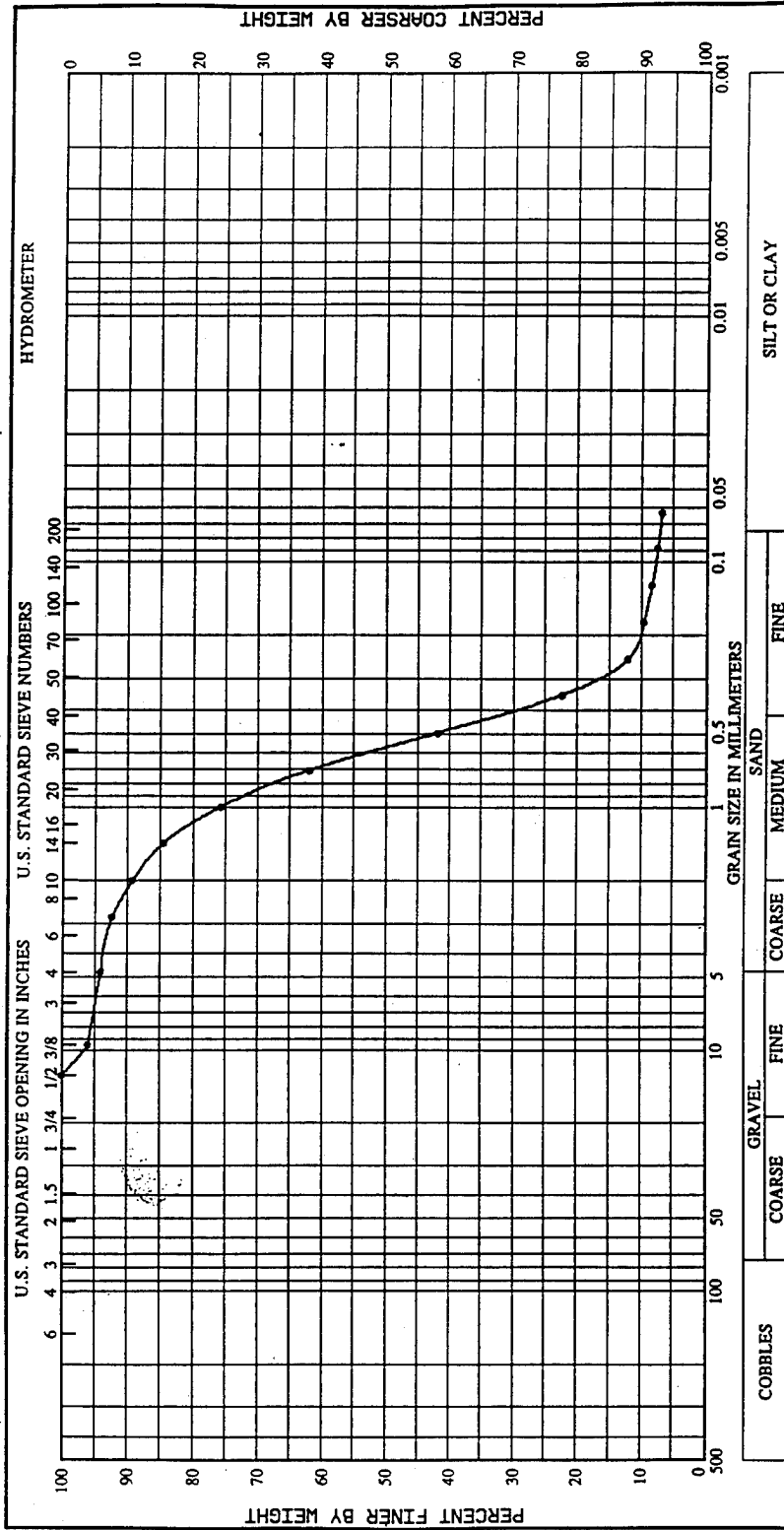
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CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



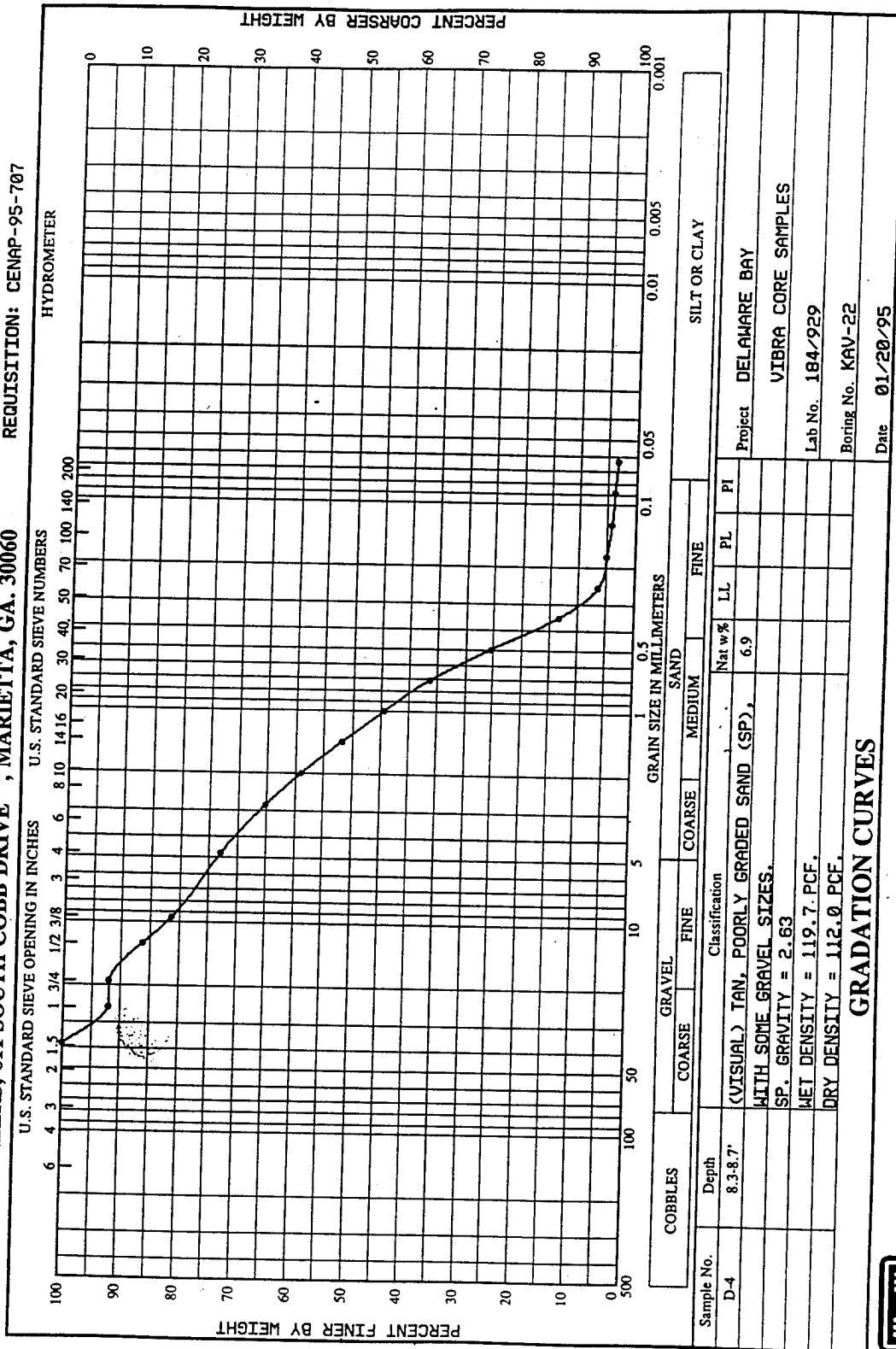
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707



DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
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| Project: <i>DELAWARE BAY</i> | | | Boring No. <i>KAV-23</i> | |
|-------------------------------------|-----------------|-------------|----------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| Location: <i>VIBRA CORE SAMPLES</i> | | | Lab No. <i>184/930</i> | |
| Boring Depth (ft): <i>12.40</i> | | Elevation: | Work order: <i>7476</i> | |
| Datum/Notes: | | | Requisition: <i>CENAP-95-707</i> | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | GRAY, SILTY SAND (SM), WITH A TRACE OF SHELL FRAGMENTS. | (Density Units = pcf) MA (A) 1.0 - 1.3' |
| | 2 | | ----- | |
| | 3 | | | |
| | 4 | | | MA D-1 3.1 - 3.6' WET DENSITY = 96.9, DRY DENSITY = 56.2, MC = 72.6 % |
| | 5 | | GRAY, LAYERED INORGANIC SILT HIGH LL (MH), WITH LENSES OF SILTY SAND (SM). | |
| | 6 | | | MA (B) 6.0 - 6.3' |
| | 7 | | ----- | |
| | 8 | | GRAY, SANDY POORLY GRADED SILTY GRAVEL (GP-GM). | SA D-2 7.4 - 7.9' WET DENSITY = 138.9, DRY DENSITY = 123.8, MC = 12.3 % |
| | 9 | | | SA (C) 8.4 - 9.2' |
| | 10 | | ----- | |
| | 11 | | TAN, POORLY GRADED SILTY SAND (SP-SM), WITH A TRACE OF GRAVEL SIZES. | SA (D) 11.0 - 11.2' |
| | 12 | | ----- | SA D-3 11.8 - 12.3' WET DENSITY = 137.3, DRY DENSITY = 116.8 MC = 13.3 % |
| | 13 | | | |
| | 14 | | | |

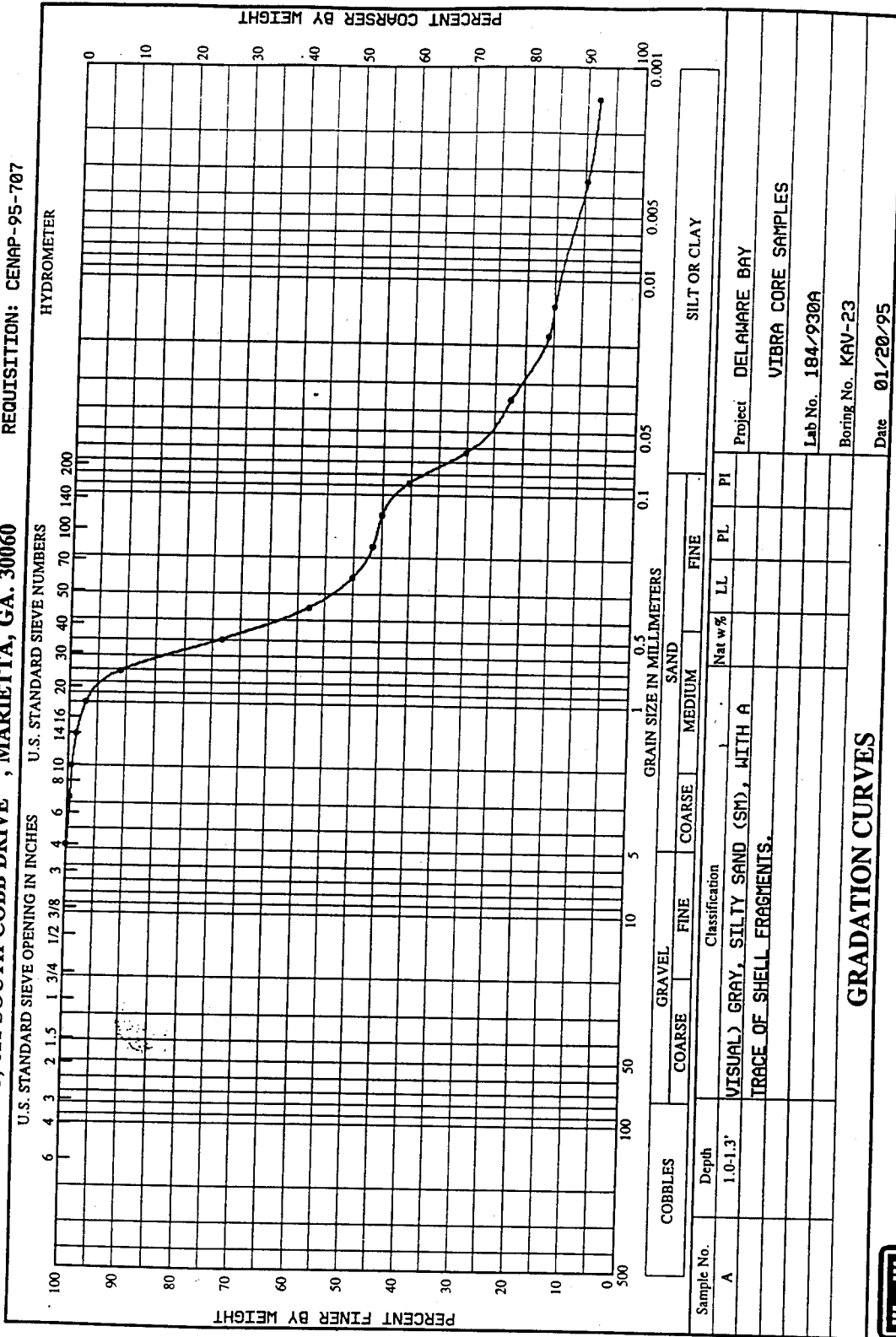
Date: *01/25/95*

LABORATORY LOG AND SAMPLE DATUM

Sheet No. *1* of *1*

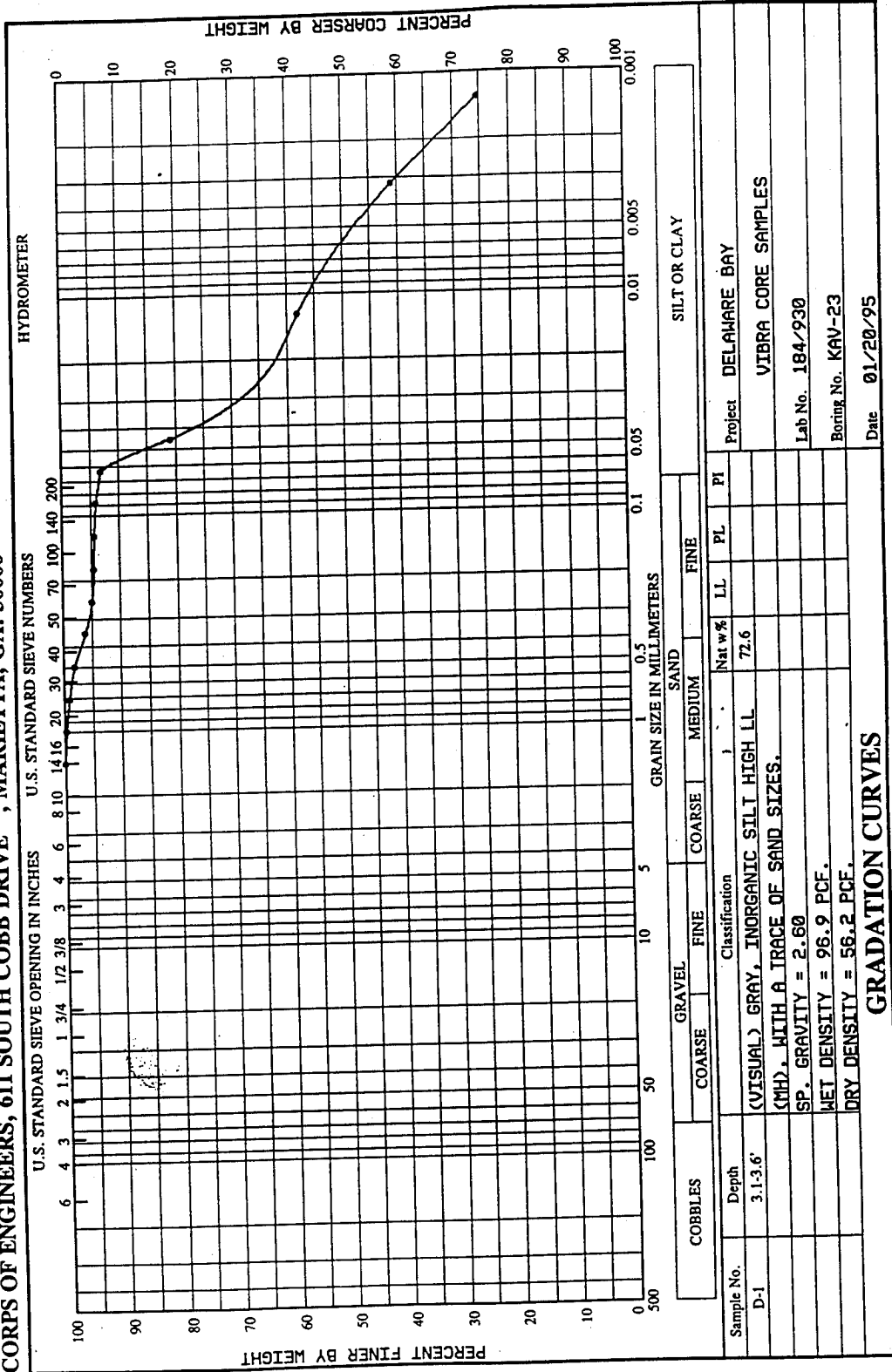
DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER: 7476
REQUISITION: CENAP-95-707

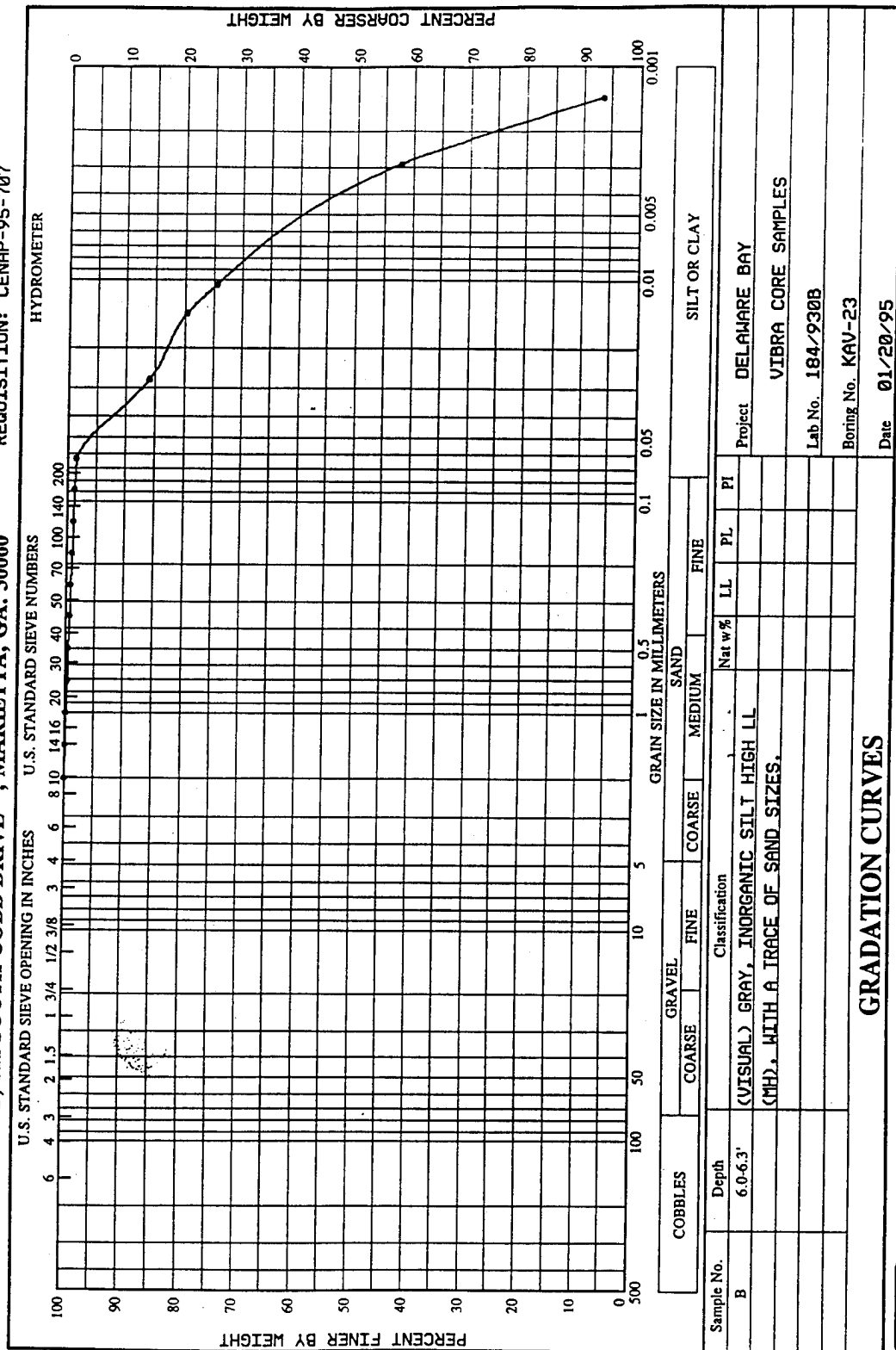


WORK ORDER: 7476
 REQUISITION: CENAP-95-707

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 CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

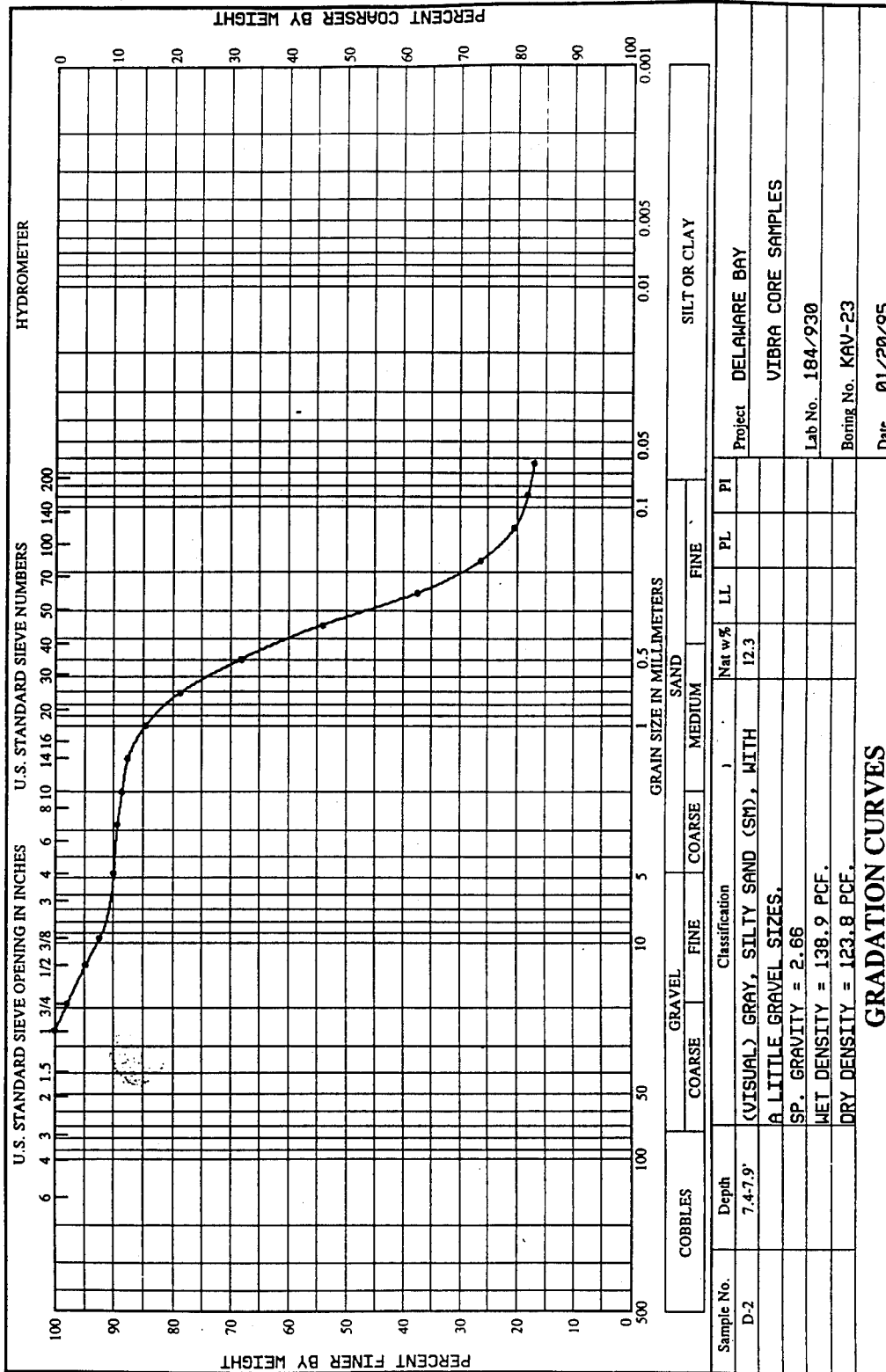


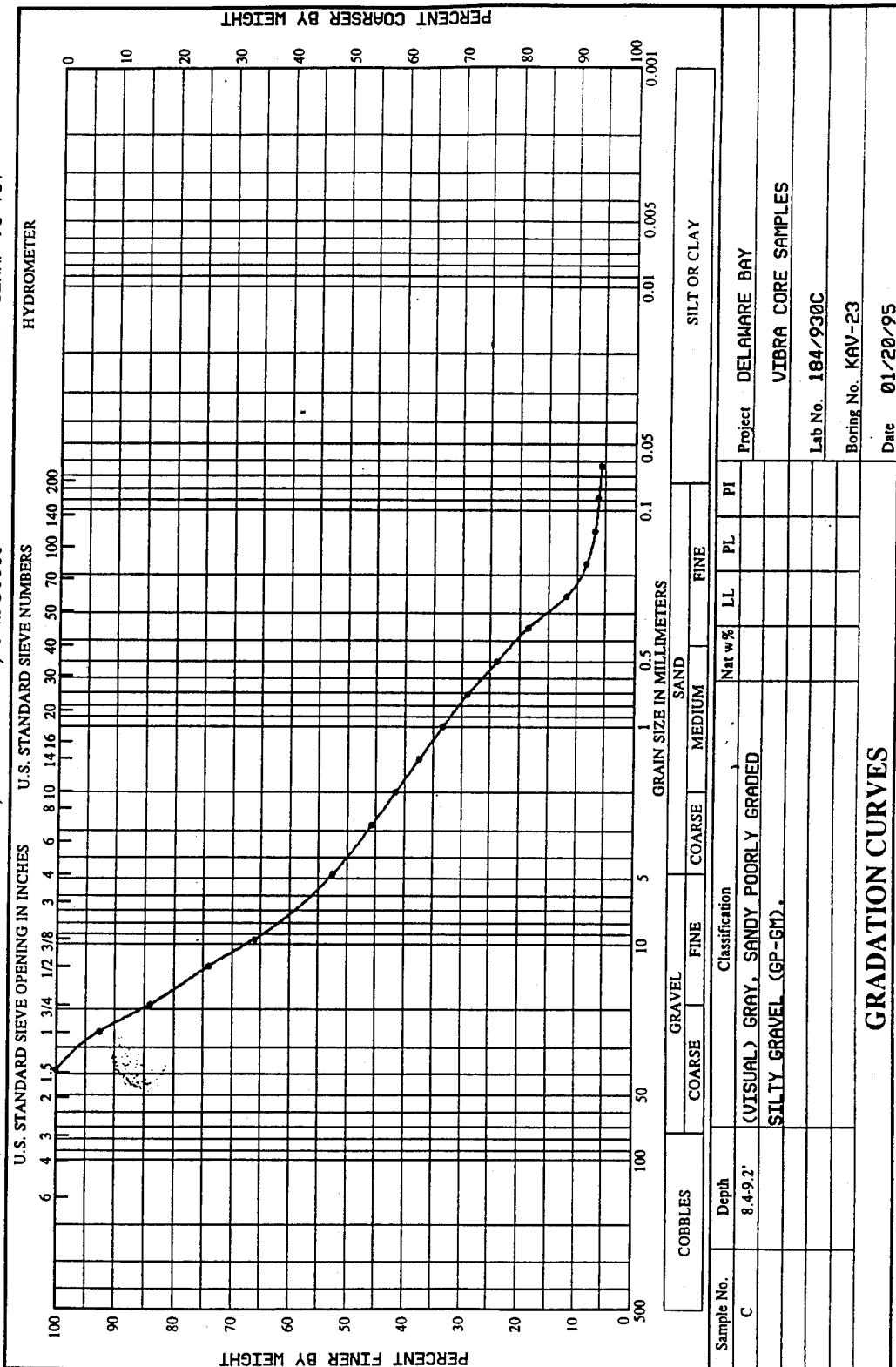
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REQUISITION: CENAP-95-707



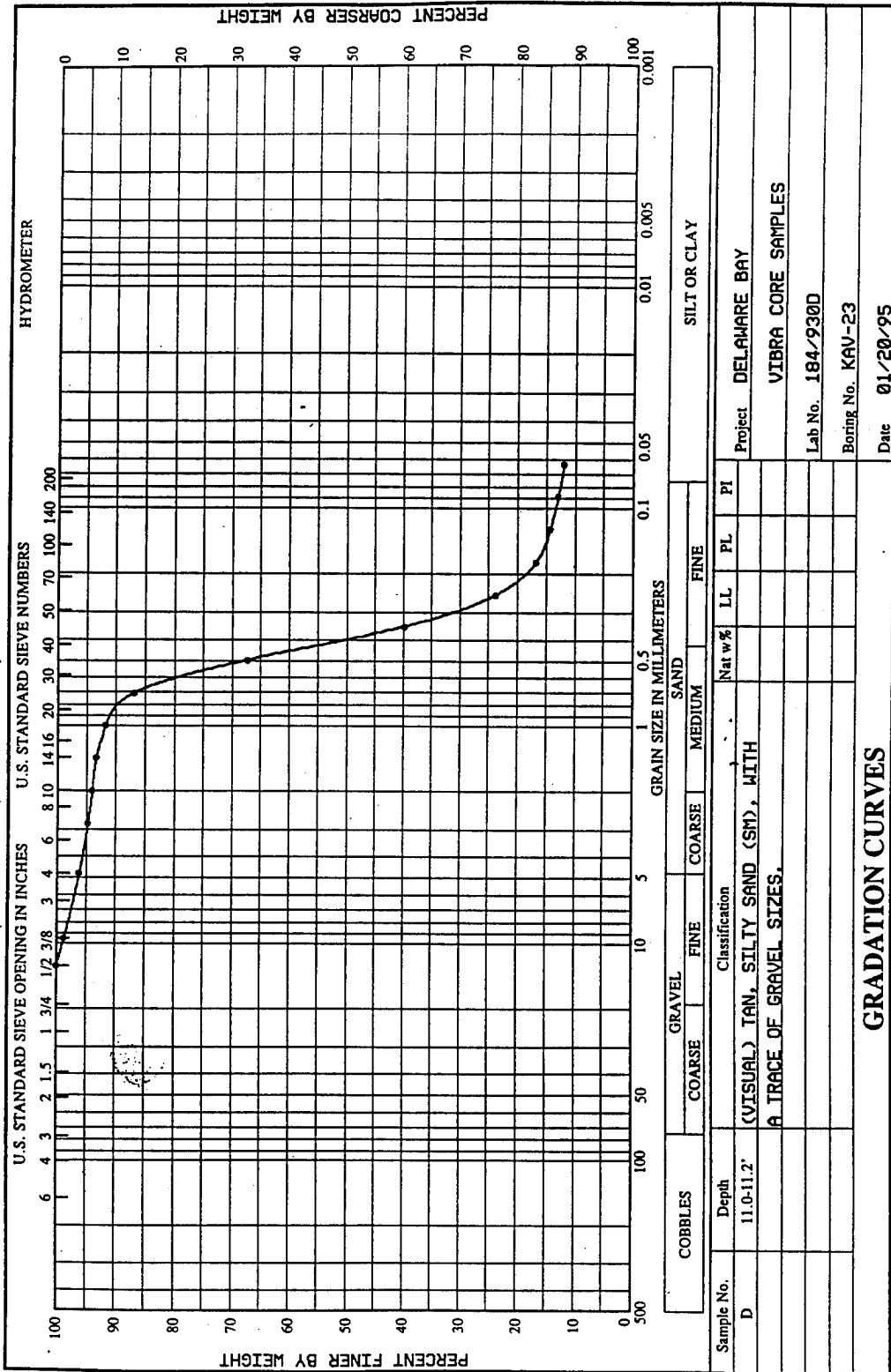
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WORK ORDER: 7476
REQUISITION: CENAP-95-707



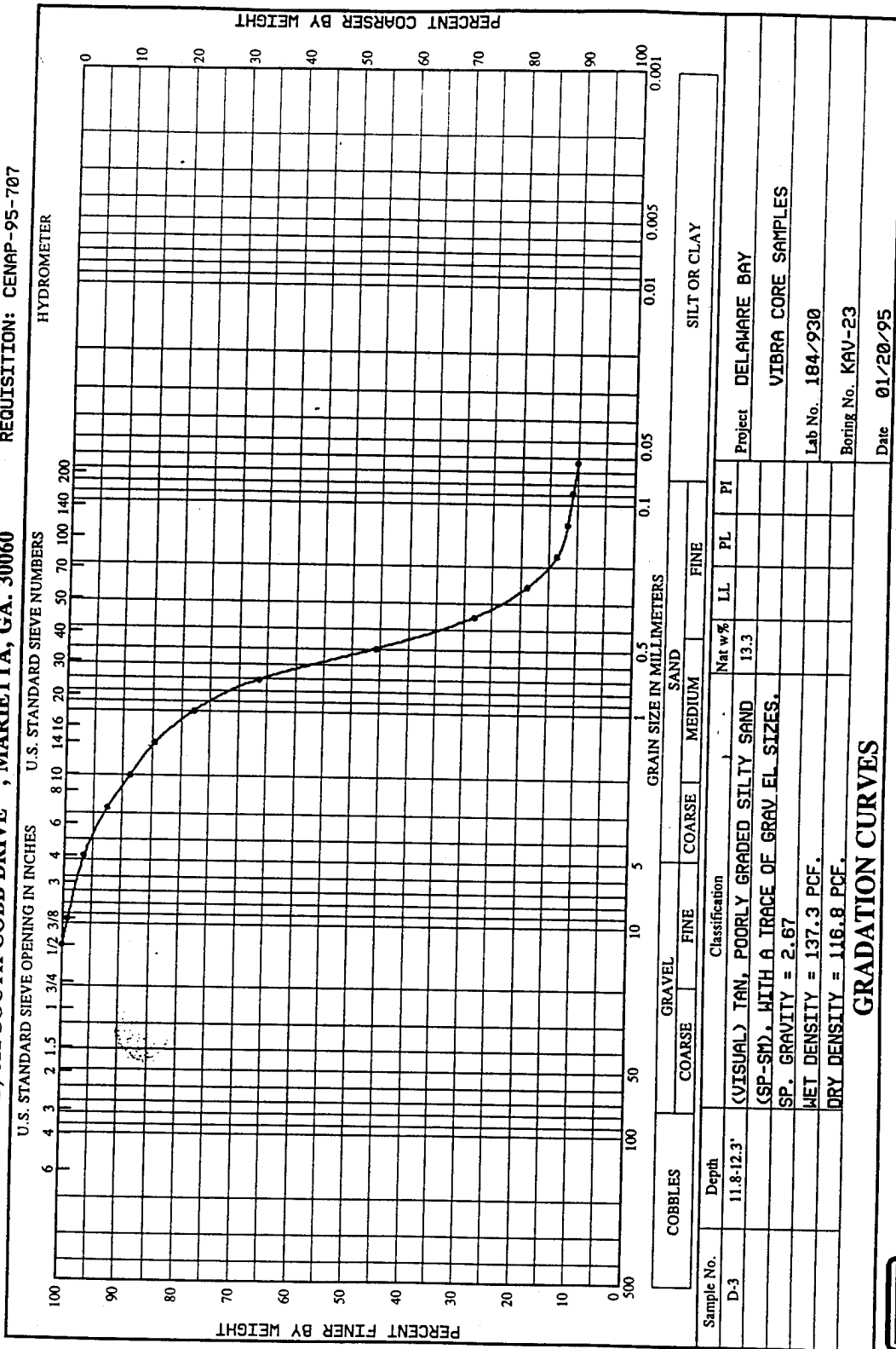


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| Project: <i>DELAWARE BAY</i> | | | Boring No. <i>KAV-24</i> | |
|-----------------------------------------------------------------------|-----------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Location: <i>VIBRA CORE SAMPLES</i> | | | Lab No. <i>184/931</i> | |
| Boring Depth (ft): <i>18.50</i> | | Elevation: | Work order: <i>7476</i> | |
| Datum/Notes: <i>See grain size data on enclosed gradation curves.</i> | | | Requisition: <i>CENAP-95-707</i> | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | GRAY, POORLY GRADED SILTY SAND (SP-SM). | (Density Units = pcf) MA (A) 0.9 - 1.2' |
| | 2 | | | |
| | 3 | | ----- TAN, POORLY GRADED SAND (SP). | SA D-1 2.5 - 3.0' WET DENSITY = 127.2, DRY DENSITY = 111.4, MC = 14.2 %. |
| | 4 | | ----- GRAY, POORLY GRADED SILTY SAND (SP-SM). | SA (B) 3.4 - 3.8' |
| | 5 | | ----- | |
| | 6 | | | |
| | 7 | | | |
| | 8 | | GRAY, INORGANIC SILT HIGH LL (MH), WITH A LITTLE SAND SIZES AND A TRACE OF MICA. | MA D-2 7.4 - 7.9' WET DENSITY = 98.9, DRY DENSITY = 62.5, MC = 58.2 %. |
| | 9 | | | |
| | 10 | | | |
| | 11 | | | MA (C) 10.4 - 10.7' |
| | 12 | | ----- TAN, POORLY GRADED SILTY SAND (SP-SM), WITH A TRACE OF GRAVEL SIZES AND POCKETS OF GRAY, INORGANIC SILT HIGH LL (MH). | SA D-3 12.0 - 12.5' WET DENSITY = 126.9, DRY DENSITY = 106.3, MC = 19.4 %. |
| | 13 | | ----- | |
| | 14 | | TAN, POORLY GRADED SAND (SP), WITH A TRACE OF GRAVEL SIZES. | SA (D) 14.2 - 14.4' |
| | 15 | | ----- | |
| | 16 | | GRAY, INORGANIC SILT HIGH LL (MH), WITH A TRACE OF SAND SIZES AND MICA. | MA D-4 15.9 - 16.4' WET DENSITY = 98.1, DRY DENSITY = 76.2, MC = 28.7 %. |
| | 17 | | ----- TANNISH GRAY, POORLY GRADED SILTY SAND (SP-SM), WITH A TRACE OF GRAVEL SIZES. | SA (E) 17.5 - 17.8' |
| | 18 | | ----- | |
| | 19 | | | |

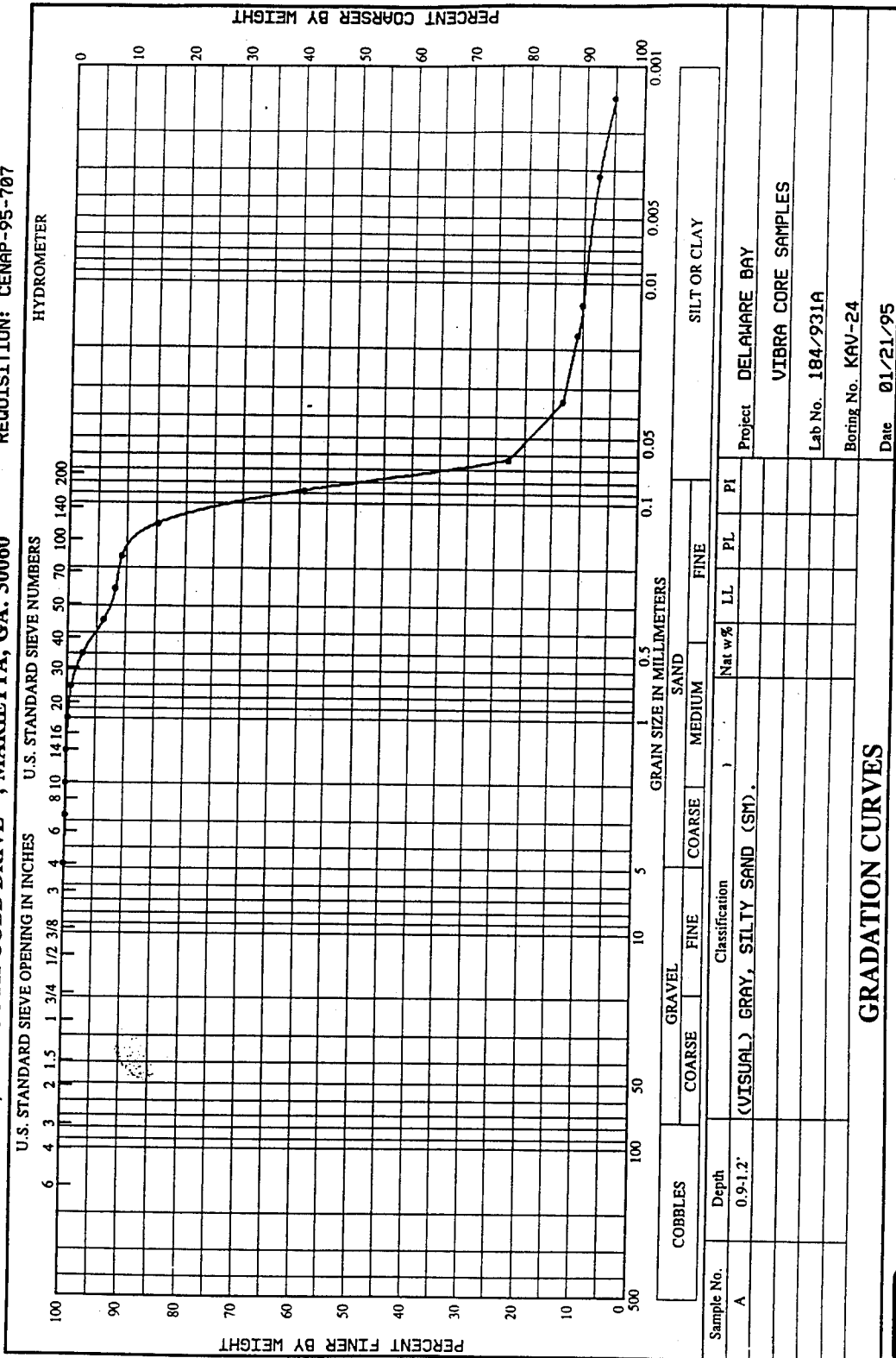
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LABORATORY LOG AND SAMPLE DATUM

Sheet No. *1* of *1*

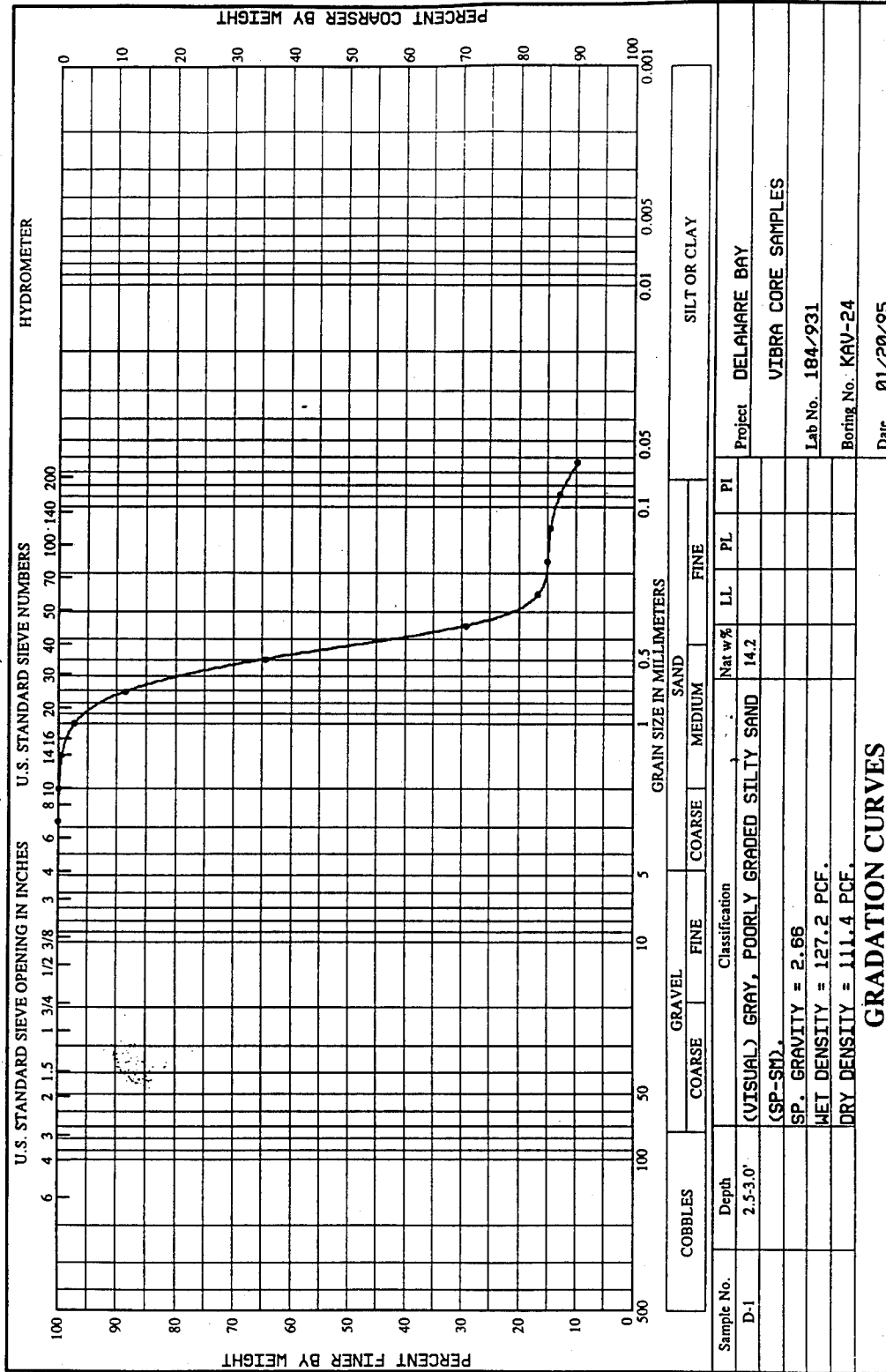
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WORK ORDER: 7476
REQUISITION: CENAP-95-707

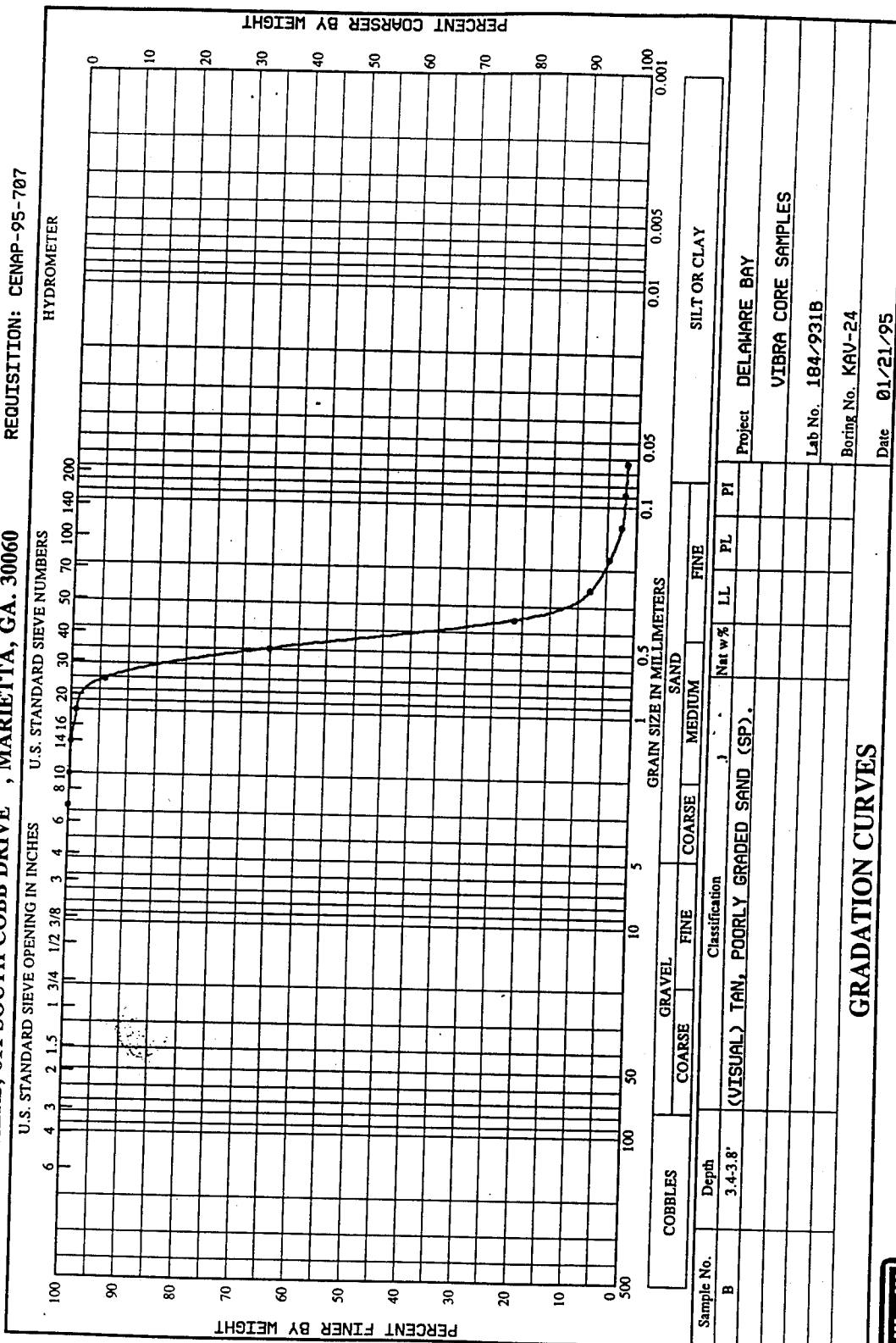


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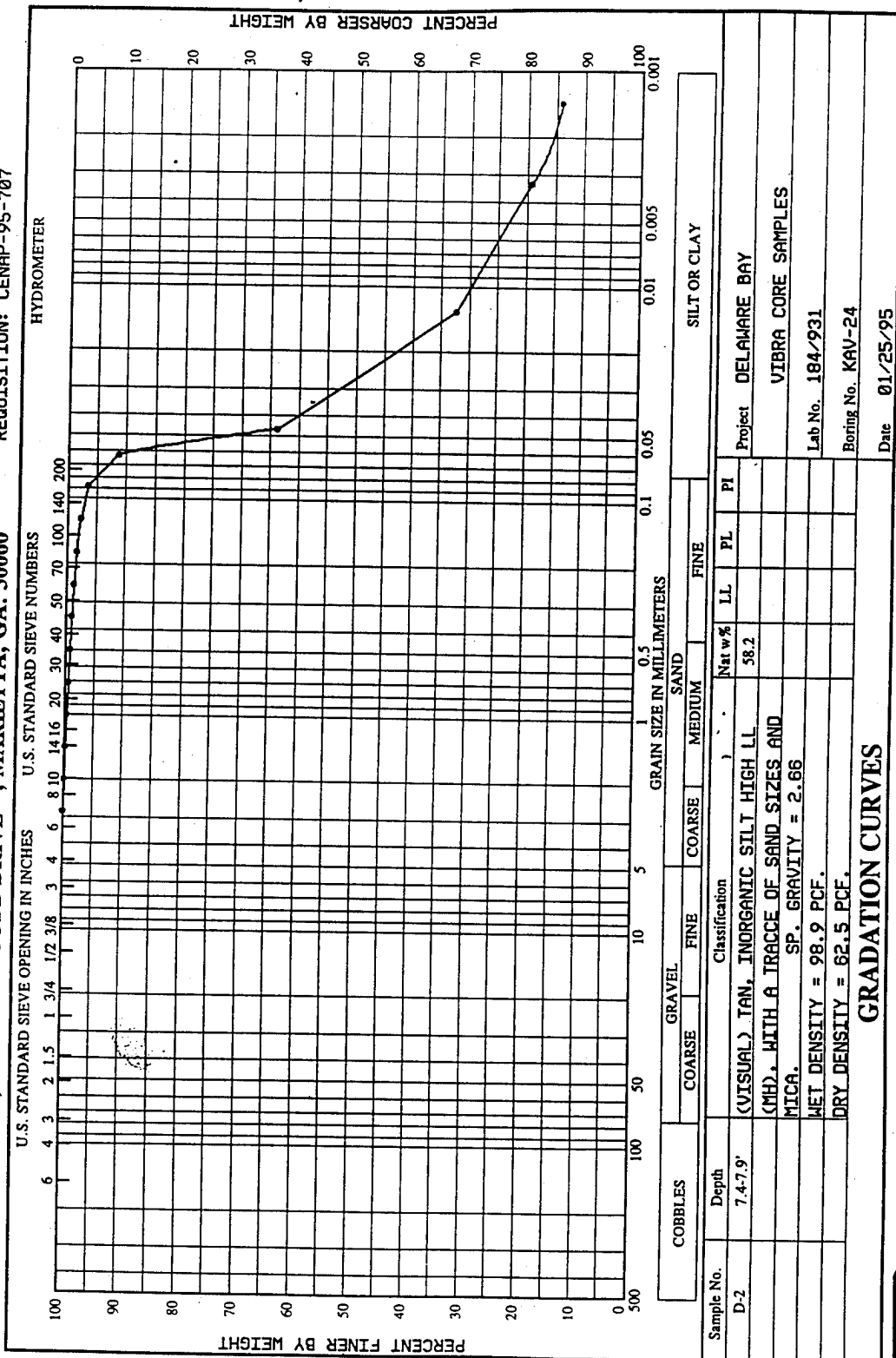


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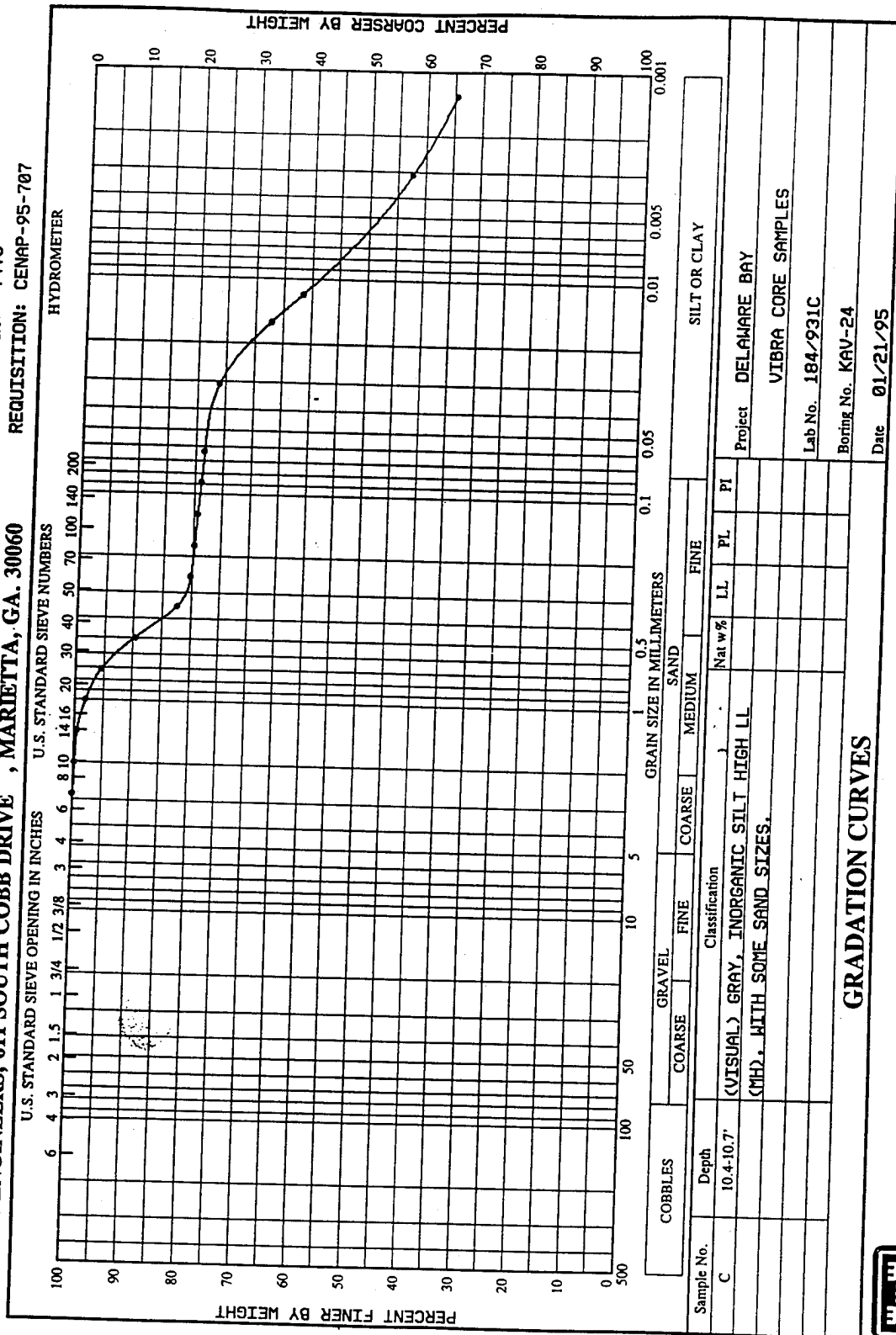
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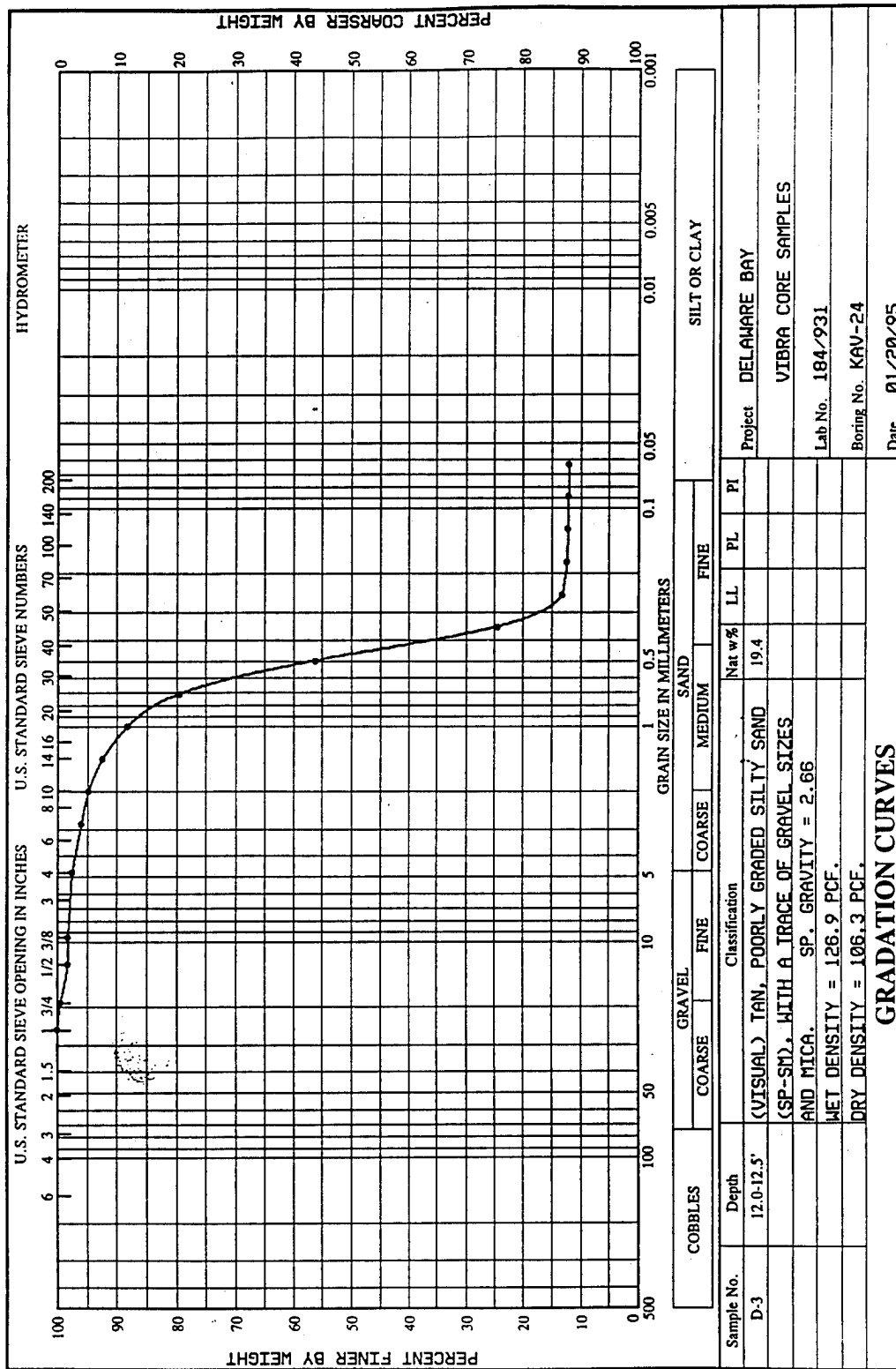
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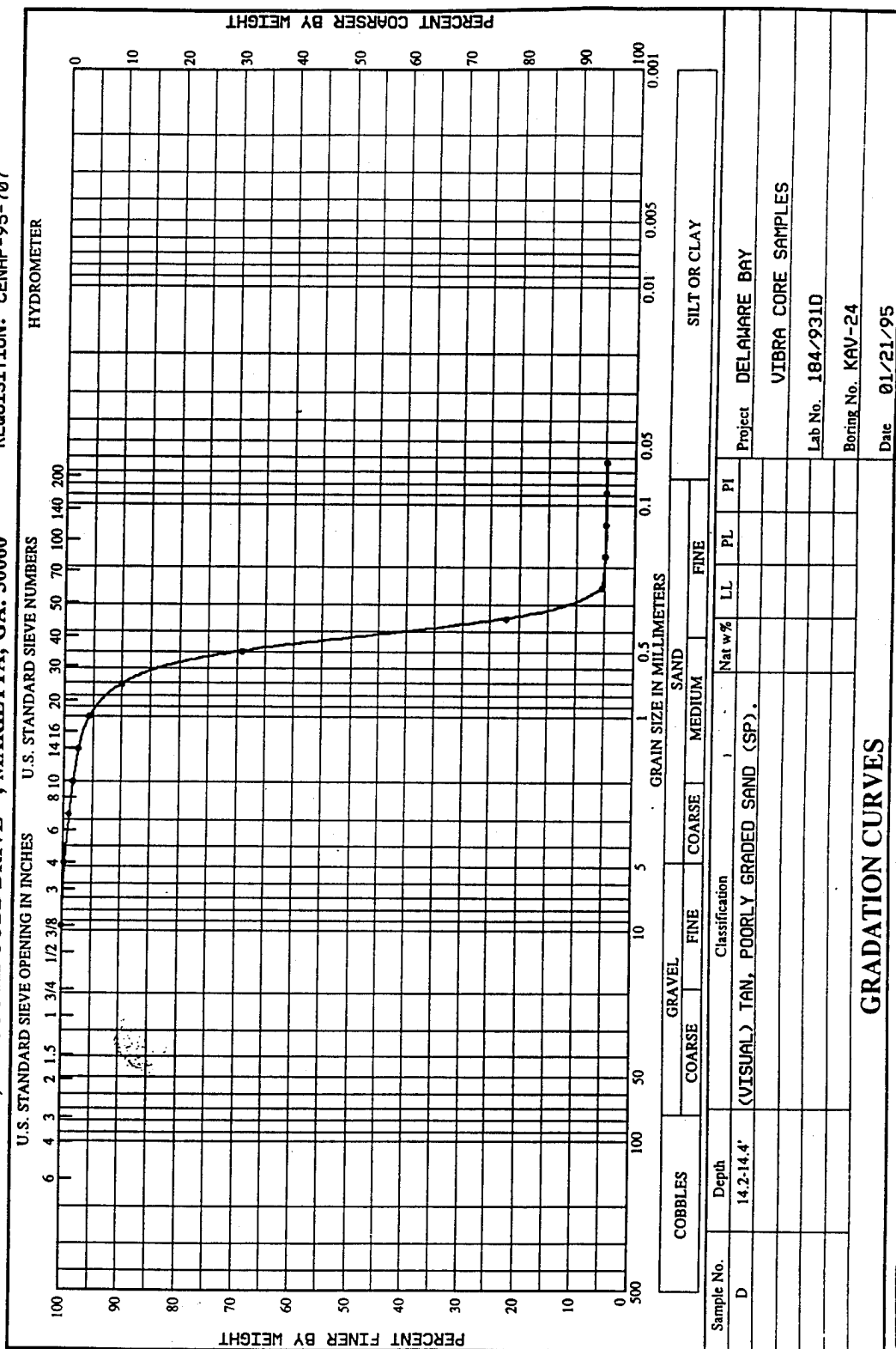
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WORK ORDER: 7476

REQUISITION: CENAP-95-707

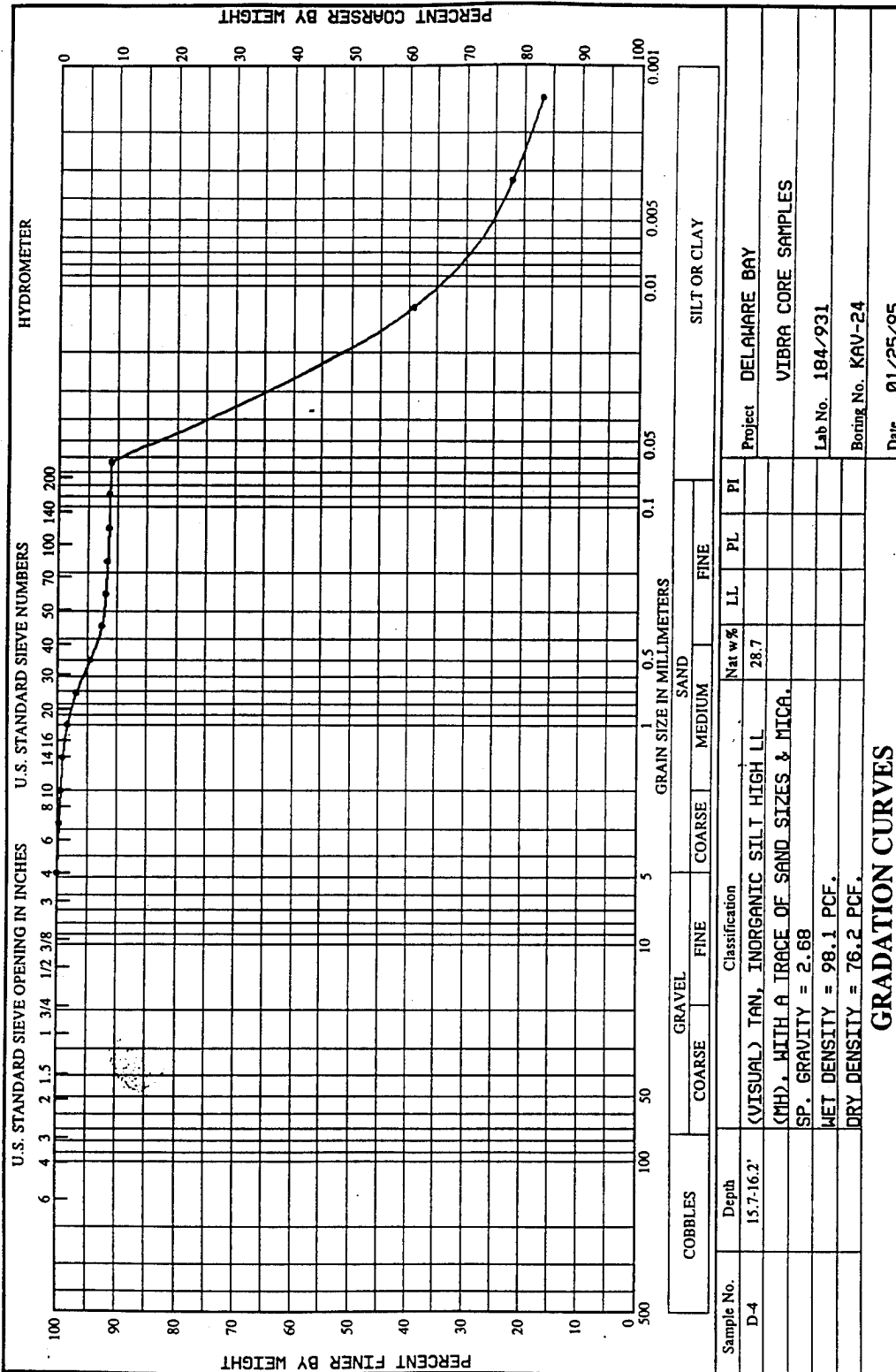


WORK ORDER: 7476
REQUISITION: CENAP-95-707



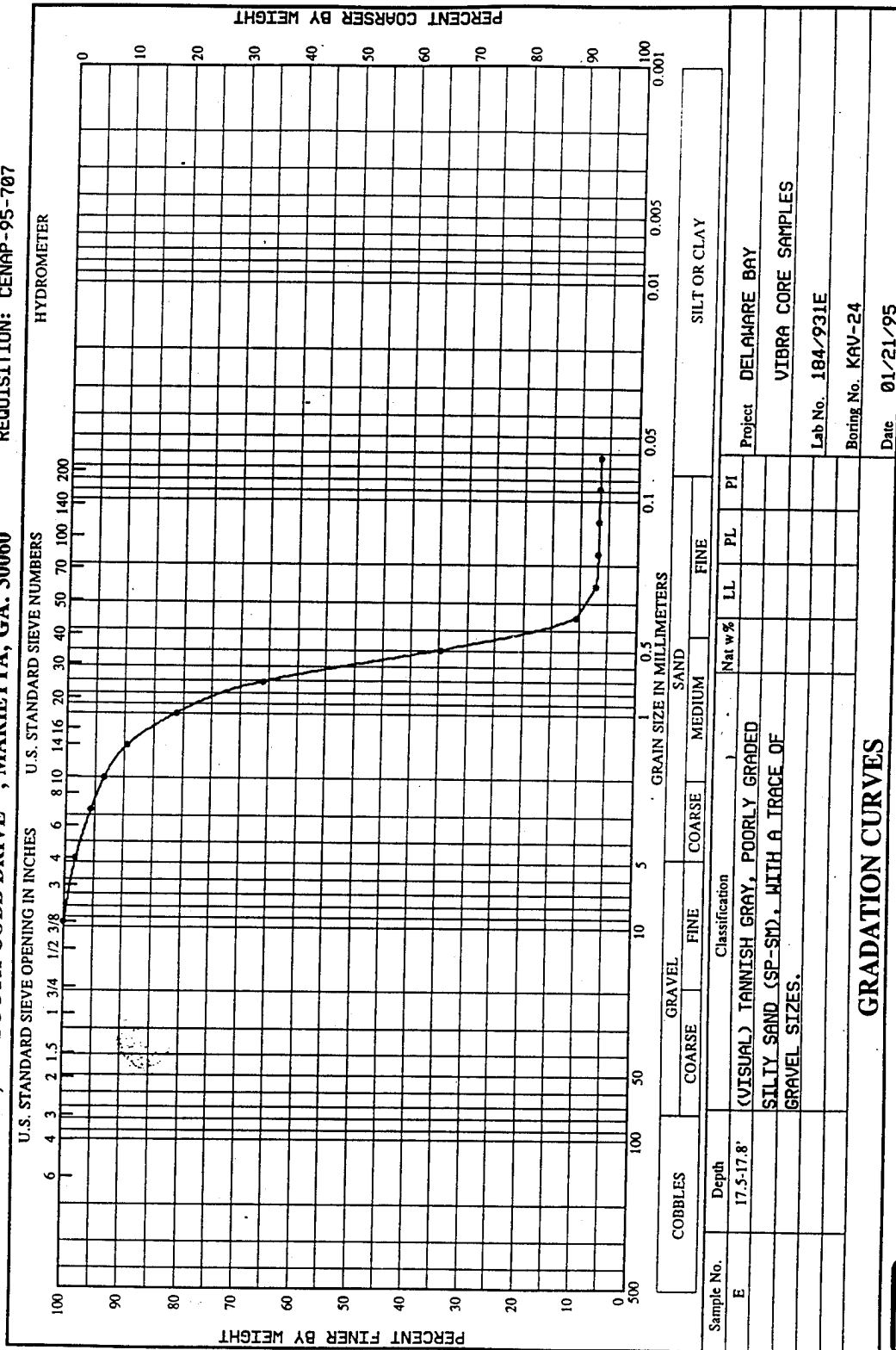
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WORK ORDER: 7476
REQUISITION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707



DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060



| Project: <i>DELAWARE BAY</i> | | | Boring No. <i>K4V-25</i> | |
|-----------------------------------------------------------------------|-----------------|-------------|--------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Location: <i>VIBRA CORE SAMPLES</i> | | | Lab No. <i>184/932</i> | |
| Boring Depth (ft): <i>17.00</i> | | Elevation: | Work order: <i>7476</i> | |
| Datum/Notes: <i>See grain size data on enclosed gradation curves.</i> | | | Requisition: <i>CENAP-95-707</i> | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | TAN AND GRAY, POORLY GRADED SAND (SP), WITH A TRACE OF GRAVEL SIZES AND GRAVEL SIZE SHELL . - ----- | (Density Units = pcf) |
| | 2 | | | SA (A) 1.2 - 1.5' |
| | 3 | | | SA D-1 2.8 - 3.3' WET DENSITY = 137.9, DRY DENSITY = 121.1, MC = 13.9 %. |
| | 4 | | | |
| | 5 | | | |
| | 6 | | | MA (B) 5.6 - 5.8' |
| | 7 | | | |
| | 8 | | | MA D-2 6.9 - 7.4' WET DENSITY = 101.2, DRY DENSITY = 62.2, MC = 62.5 %. |
| | 9 | | GRAY, INORGANIC SILT HIGH LL (MH), WITH OCCASIONAL LENSES OF POORLY GRADED SILTY SAND (SP-SM) AND A TRACE OF MICA. | MA (C) 8.9 - 9.2' |
| | 10 | | | |
| | 11 | | | MA (D) 11.3 - 11.5' |
| | 12 | | | |
| | 13 | | | MA D-3 13.4 - 13.9' WET DENSITY = 105.2, DRY DENSITY = 66.3, MC = 58.7 %. |
| | 14 | | | |
| | 15 | | | MA (E) 15.1 - 15.4' |
| | 16 | | | |
| | 17 | | ----- | MA D-4 16.5 - 17.0' WET DENSITY = 92.6, DRY DENSITY = 55.7, MC = 66.2 %. |

Date: 01/21/95

LABORATORY LOG AND SAMPLE DATUM

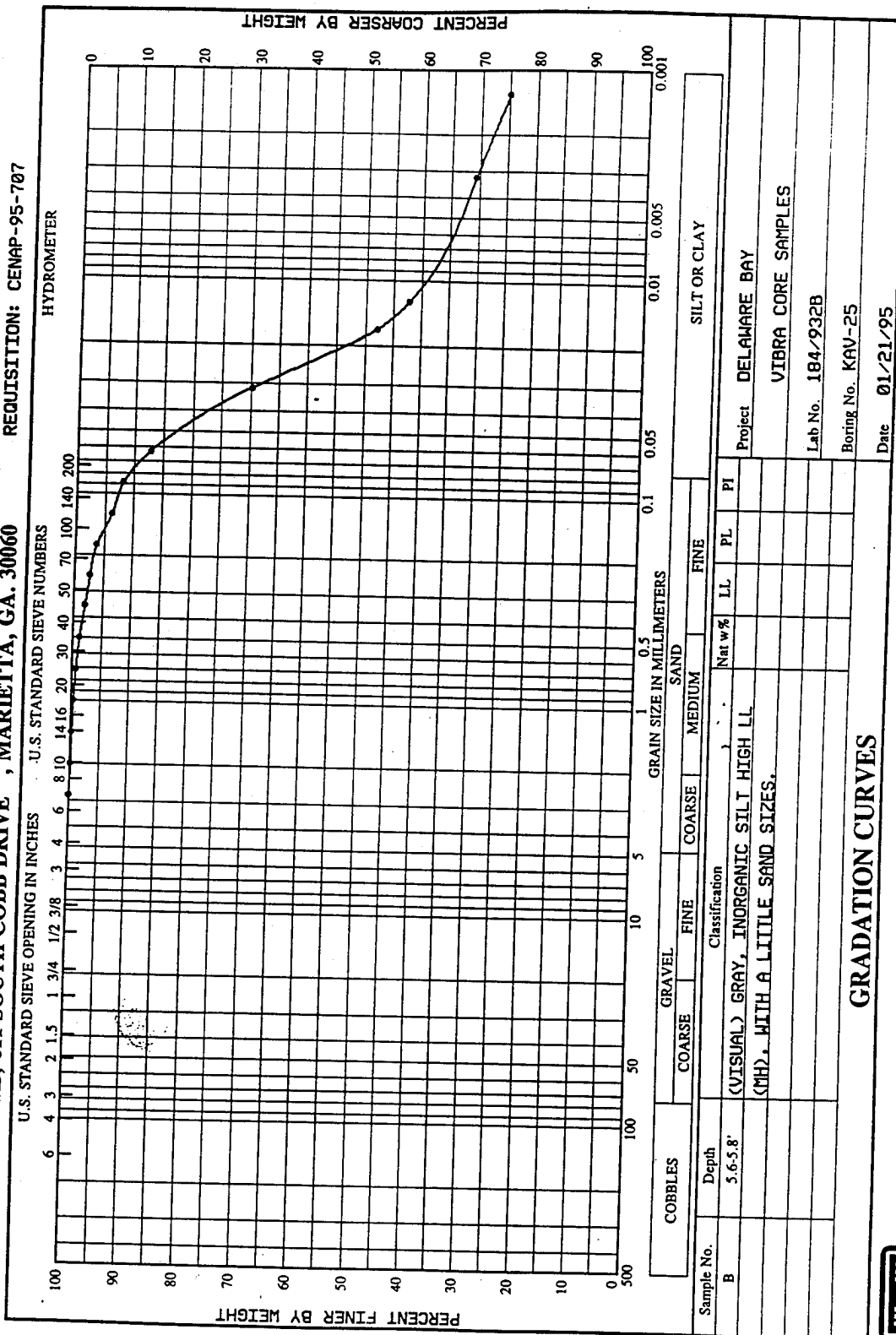
Sheet No. 1 of 1

WORK ORDER: 7476
REQUISITION: CENAP-95-707



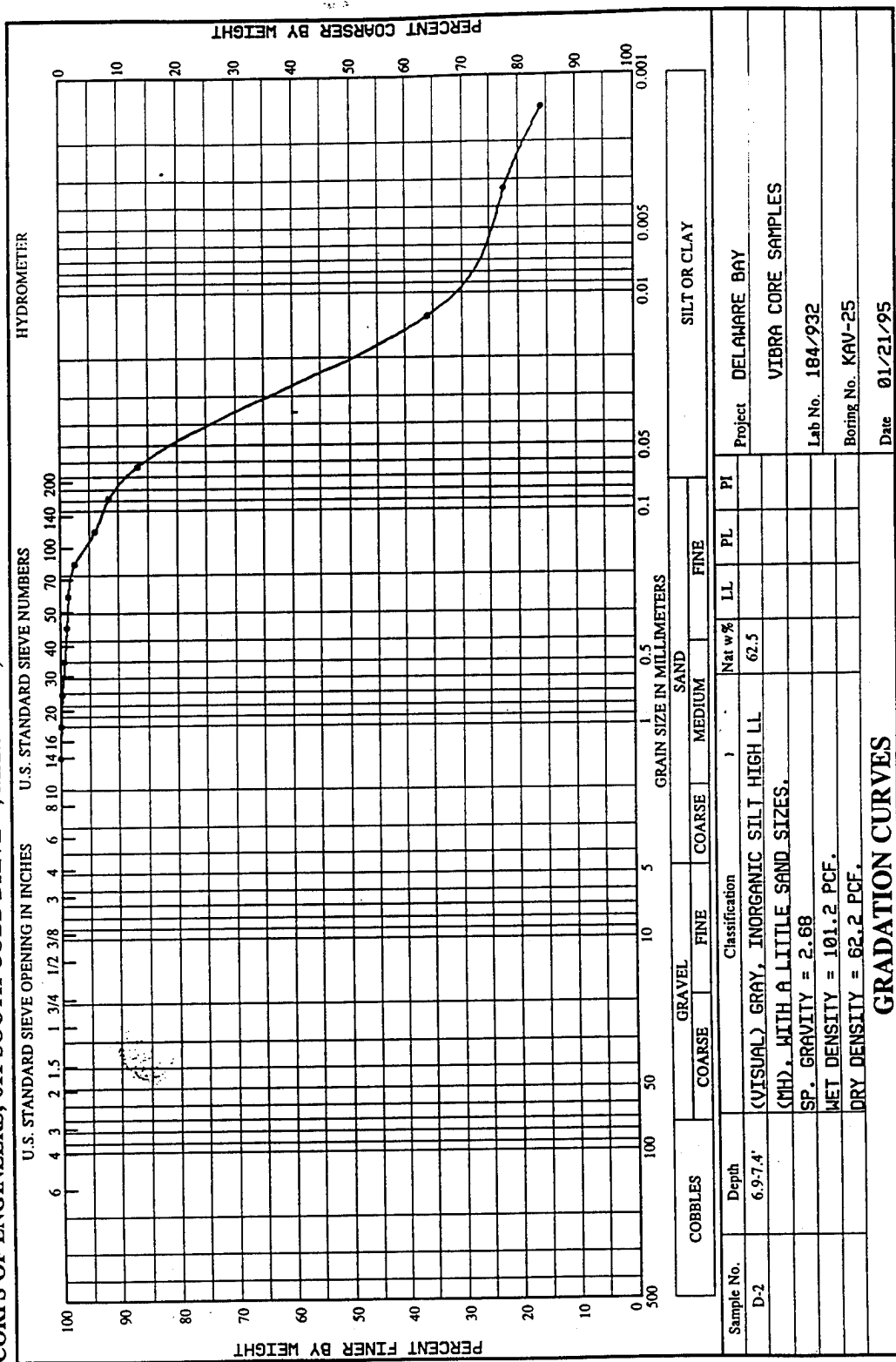
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REQUISITION: CENAP-95-707



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U.S. STANDARD SIEVE OPENING IN INCHES

U.S. STANDARD SIEVE NUMBERS

PERCENT FINER BY WEIGHT

PERCENT COARSER BY WEIGHT

HYDROMETER

GRAIN SIZE IN MILLIMETERS

COBBLES

GRAVEL

COARSE

FINE

COARSE

MEDIUM

FINE

SAND

COARSE

MEDIUM

FINE

SILT OR CLAY

Sample No. C

Depth 8.9-9.2'

Classification (VISUAL) GRAY, INORGANIC SILT HIGH LL (MH), WITH A TRACE OF SAND.

Project DELAWARE BAY

VIBRA CORE SAMPLES

Lab No. 184/932C

Boring No. KAV-25

Date 01/21/95

GRADATION CURVES

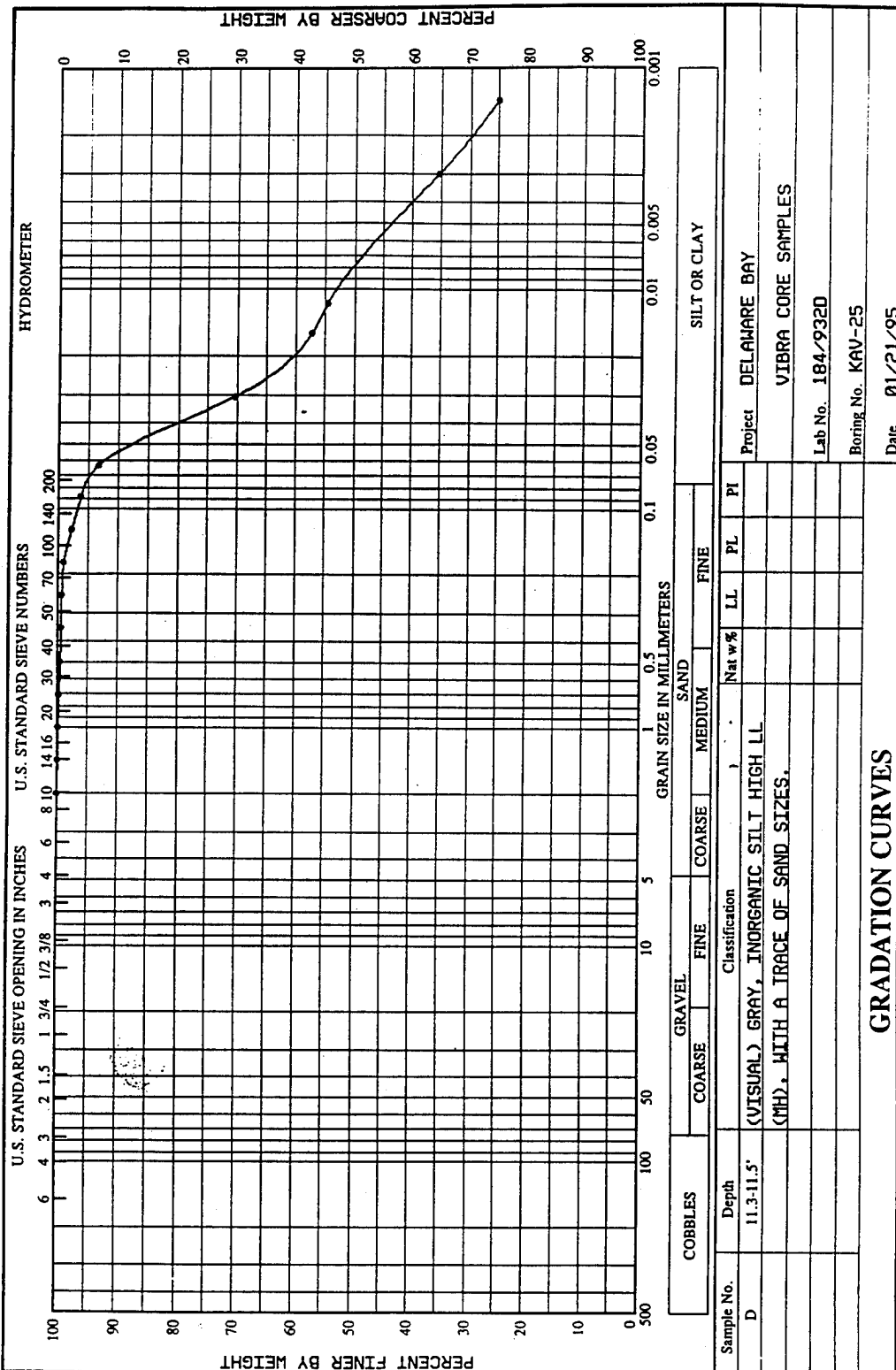
| Sample No. | Depth | Classification | Project |
|------------|----------|-------------------------------------------------------------------|--------------|
| C | 8.9-9.2' | (VISUAL) GRAY, INORGANIC SILT HIGH LL (MH), WITH A TRACE OF SAND. | DELAWARE BAY |

| U.S. STANDARD SIEVE OPENING IN INCHES | U.S. STANDARD SIEVE NUMBERS | PERCENT FINER BY WEIGHT |
|---------------------------------------|-----------------------------|-------------------------|
| 6 | 100 | 100 |
| 4 | 40 | 100 |
| 3 | 60 | 100 |
| 2 | 80 | 100 |
| 1.5 | 100 | 100 |
| 1 | 16 | 100 |
| 3/4 | 20 | 100 |
| 1/2 | 30 | 100 |
| 3/8 | 40 | 100 |
| 1/4 | 60 | 100 |
| 3 | 60 | 100 |
| 4 | 40 | 100 |
| 6 | 25 | 100 |
| 8 | 20 | 100 |
| 10 | 16 | 100 |
| 14 | 10 | 100 |
| 20 | 75 | 100 |
| 30 | 60 | 100 |
| 40 | 40 | 100 |
| 60 | 25 | 100 |
| 80 | 20 | 100 |
| 100 | 16 | 100 |
| 150 | 10 | 100 |
| 200 | 75 | 100 |
| 250 | 60 | 100 |
| 300 | 50 | 100 |
| 350 | 45 | 100 |
| 400 | 40 | 100 |
| 450 | 35 | 100 |
| 500 | 30 | 100 |
| 600 | 25 | 100 |
| 700 | 20 | 100 |
| 800 | 18 | 100 |
| 900 | 16 | 100 |
| 1000 | 15 | 100 |
| 1250 | 12 | 100 |
| 1500 | 10 | 100 |
| 1750 | 9 | 100 |
| 2000 | 8 | 100 |
| 2500 | 6 | 100 |
| 3000 | 5 | 100 |
| 3500 | 4 | 100 |
| 4000 | 3 | 100 |
| 4500 | 3 | 100 |
| 5000 | 3 | 100 |
| 6000 | 2 | 100 |
| 7000 | 2 | 100 |
| 8000 | 2 | 100 |
| 9000 | 2 | 100 |
| 10000 | 2 | 100 |
| 12500 | 1 | 100 |
| 15000 | 1 | 100 |
| 17500 | 1 | 100 |
| 20000 | 1 | 100 |
| 25000 | 1 | 100 |
| 30000 | 1 | 100 |
| 35000 | 1 | 100 |
| 40000 | 1 | 100 |
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| 50000 | 1 | 100 |
| 60000 | 1 | 100 |
| 70000 | 1 | 100 |
| 80000 | 1 | 100 |
| 90000 | 1 | 100 |
| 100000 | 1 | 100 |



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WORK ORDER: 7476
REQUISITION: CENAP-95-707

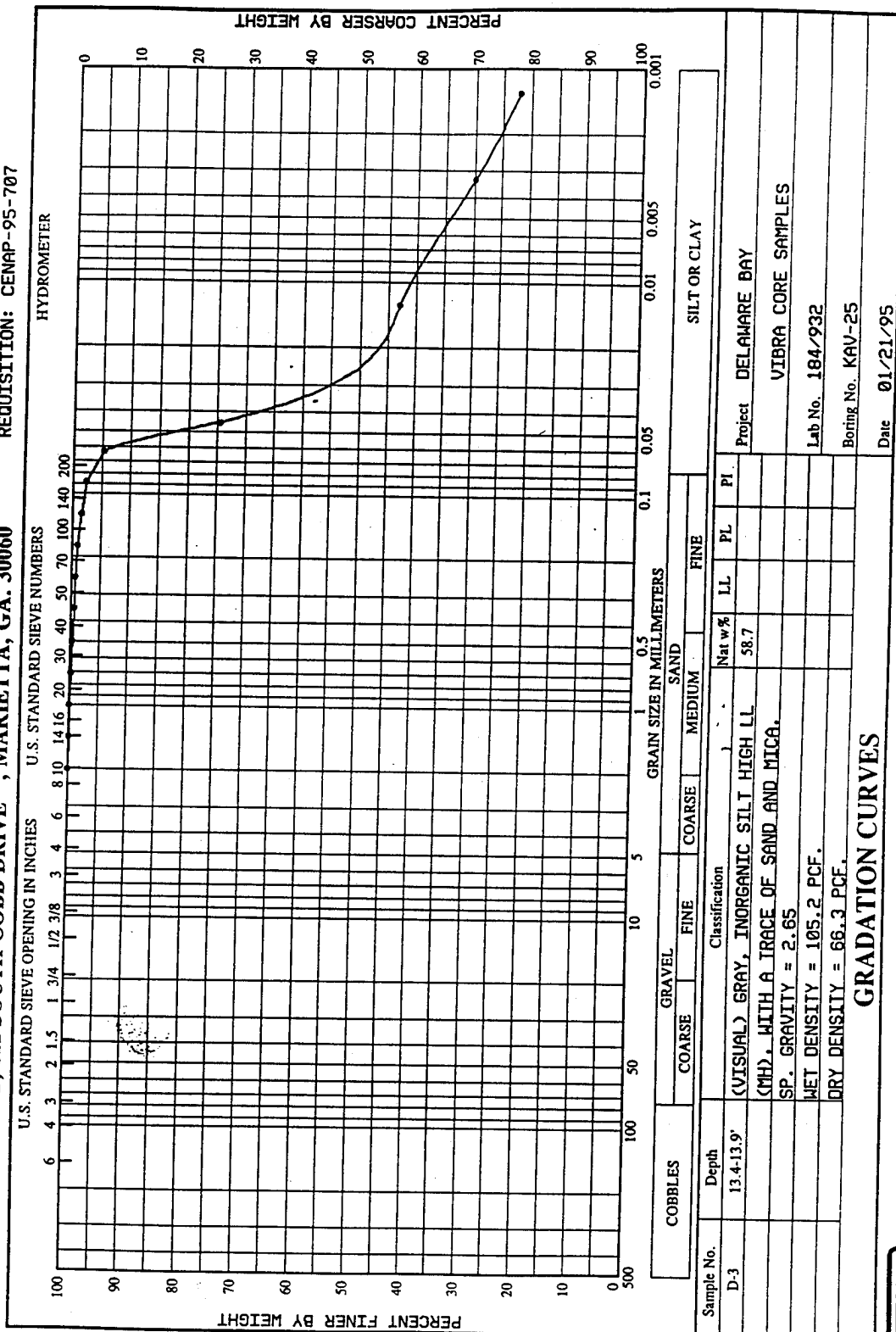


GRADATION CURVES



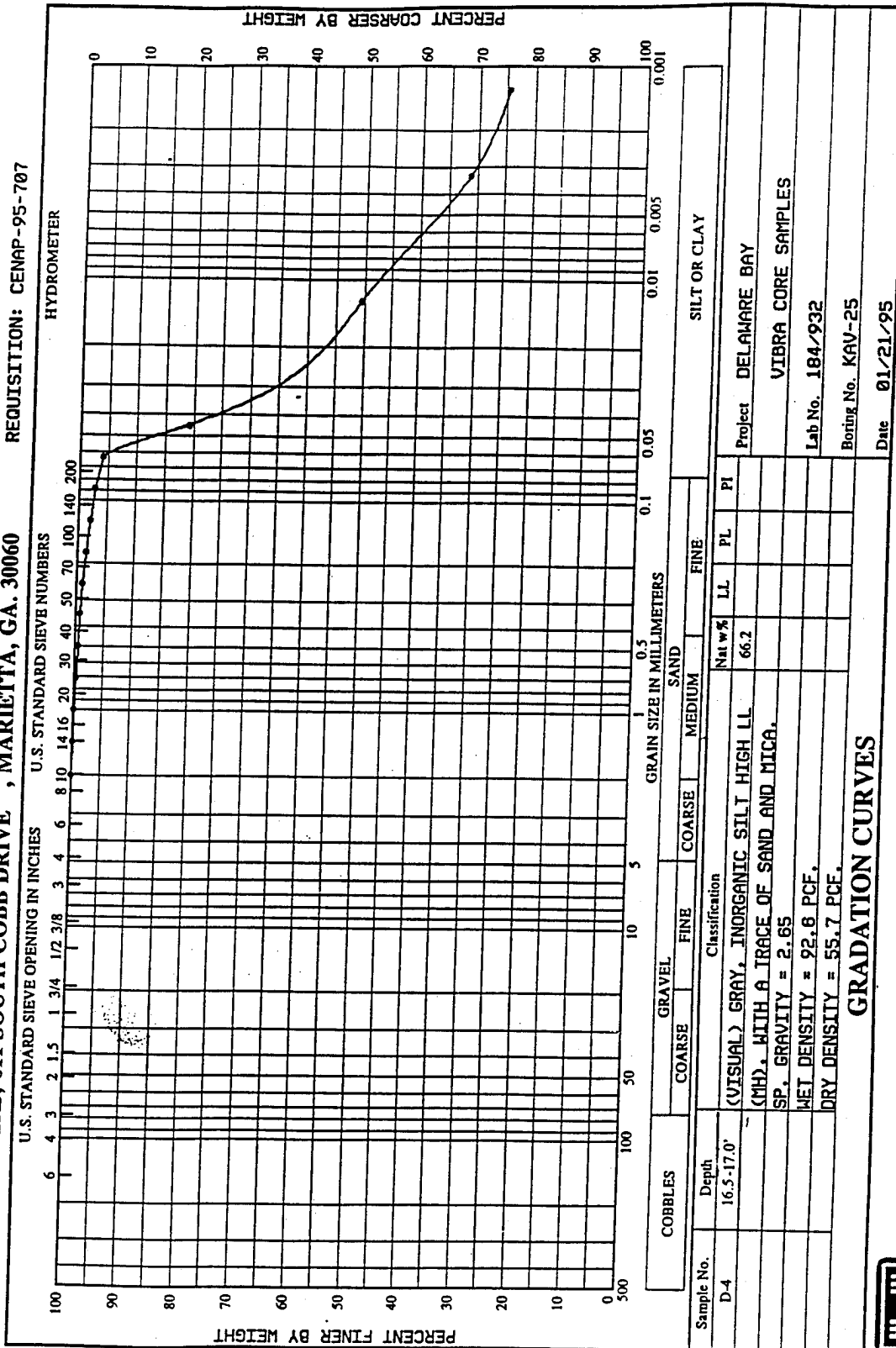
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WORK ORDER: 7476
REDUSSION: CENAP-95-707



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WORK ORDER: 7476
REQUISITION: CENAP-95-707



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| Project: DELAWARE BAY | | | Boring No. KAV-26 | |
|----------------------------------------------------------------|-----------------|-------------|-----------------------------------------------------------------|-----------------------------------------------------------------------------|
| Location: VIBRA CORE SAMPLES | | | Lab No. 184/933 | |
| Boring Depth (ft): 15.30 | | Elevation: | | Work order: 7476 |
| Datum/Notes: See grain size data on enclosed gradation curves. | | | Requisition: CENAP-95-707 | |
| Elev. (feet) | Depth (feet) | Leg- end | Material Description | Comments |
| | 1 | | LT. BROWN, POORLY GRADED SILTY SAND (SP-SM). | (Density Units = pcf) |
| | 2 | | GRAY, SILTY SAND (SM), WITH A TRACE OF GRAVEL SIZES. | MA (A) 1.1 - 1.3' |
| | 3 | | GRAY, GRAVELLY POORLY GRADED SAND (SP). | SA D-1 3.0 - 3.5' WET DENSITY = 137.8, DRY DENSITY = 131.0, MC = 5.2 |
| | 4 | | | |
| | 5 | | | |
| | 6 | | GRAY, POORLY GRADED SILTY SAND (SP-SM). | SA (B) 6.1 - 6.3' |
| | 7 | | | |
| | 8 | | | SA D-2 7.2 - 7.7' WET DENSITY = 137.8, DRY DENSITY = 121.8, MC = 13.2 % |
| | 9 | | GRAY, POORLY GRADED SILTY SAND (SP-SM), WITH SOME GRAVEL SIZES. | SA (C) 9.0 - 9.5' |
| | 10 | | | |
| | 11 | | GRAY, POORLY GRADED SAND (SP), WITH A TRACE OF GRAVEL SIZES. | SA (D) 11.5 - 11.8' |
| | 12 | | | |
| | 13 | | | SA D-3 12.5 - 13.0' WET DENSITY = 125.4, DRY DENSITY = 117.2, MC = 7.0 % |
| | 14 | | GRAY, POORLY GRADED SAND (SP), WITH A TRACE OF GRAVEL SIZES. | SA (E) 13.6 - 14.1' |
| | 15 | | | |

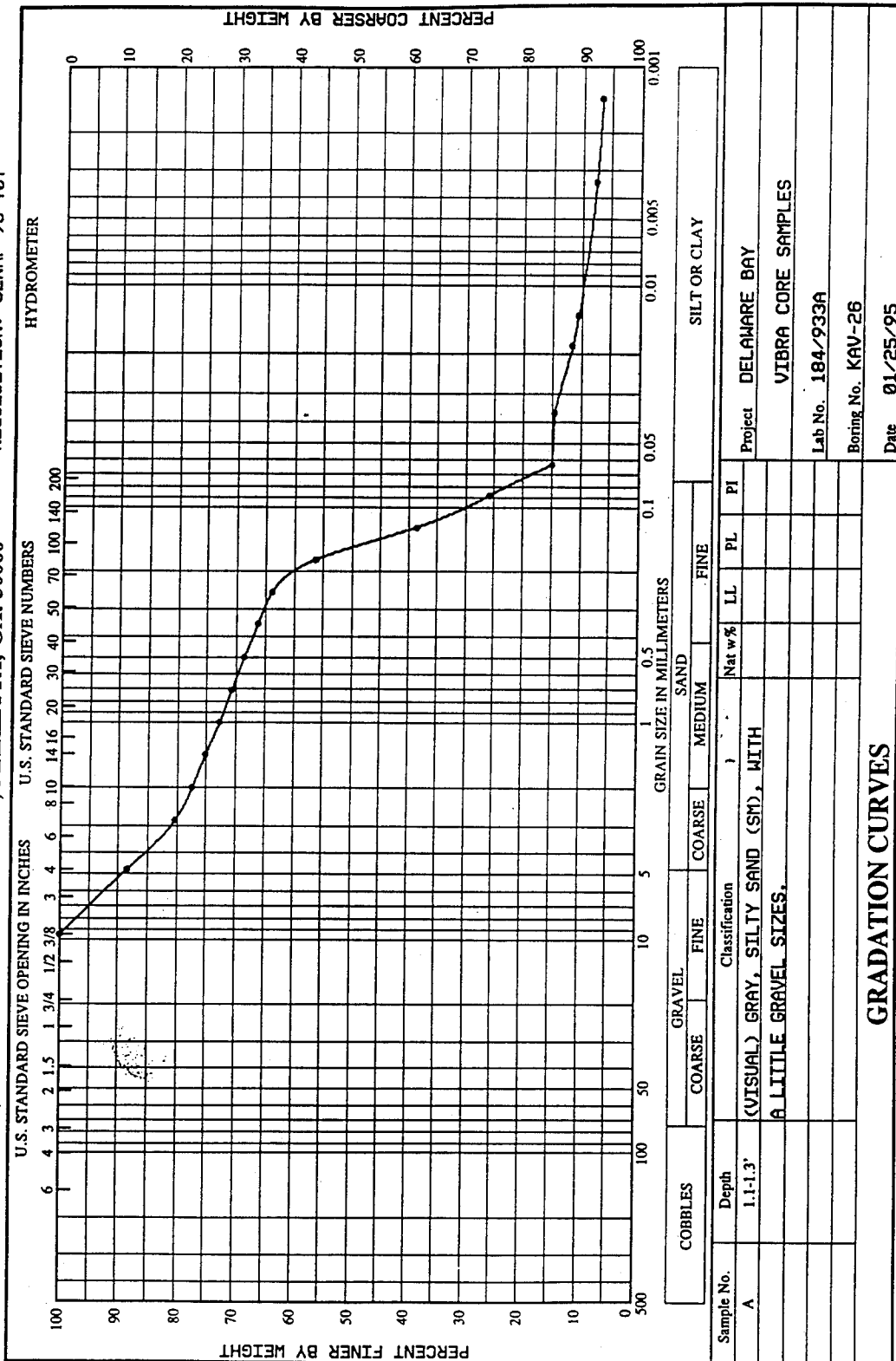
Date: 01/21/95

LABORATORY LOG AND SAMPLE DATUM

Sheet No. 1 of 1

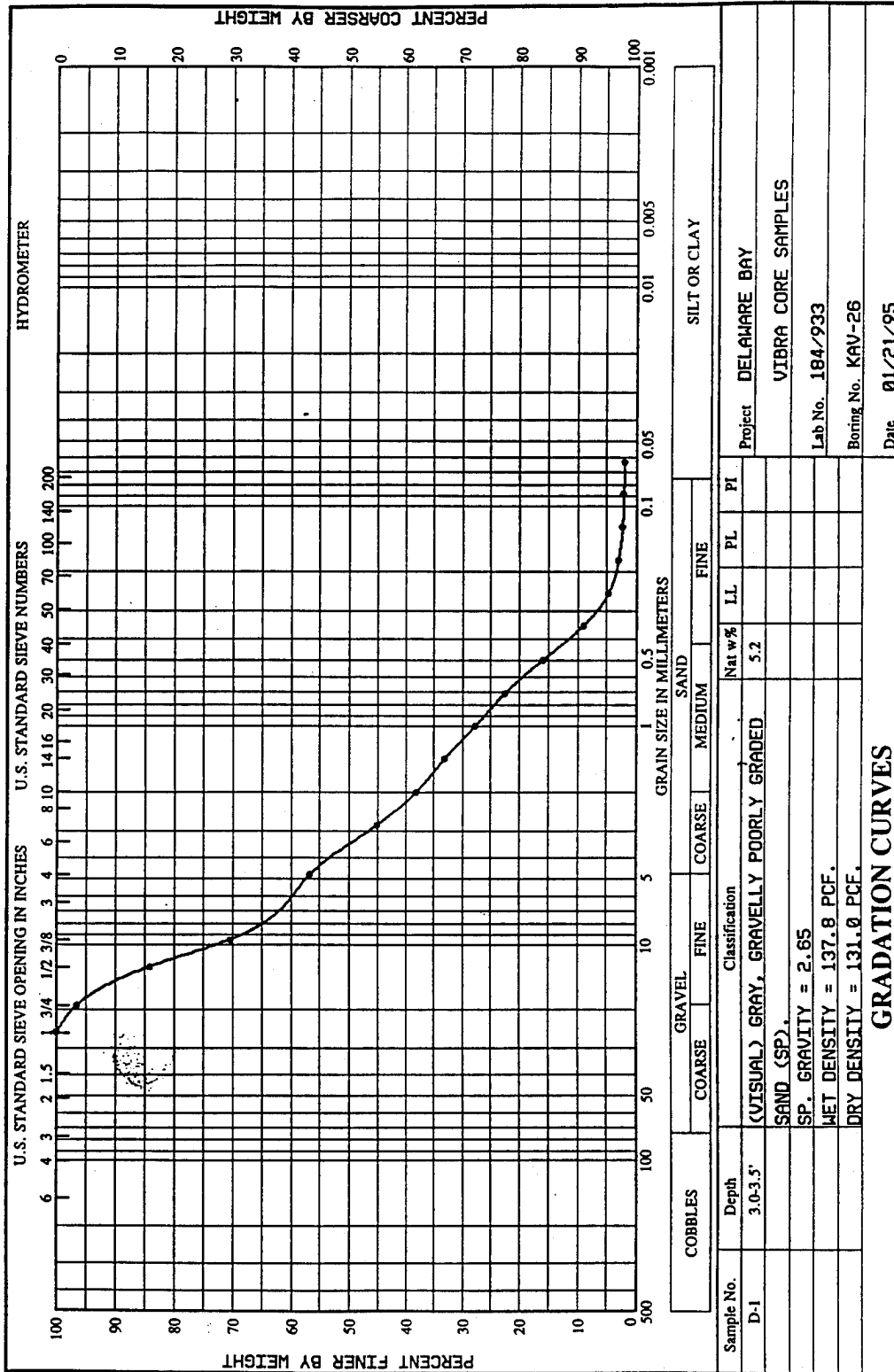
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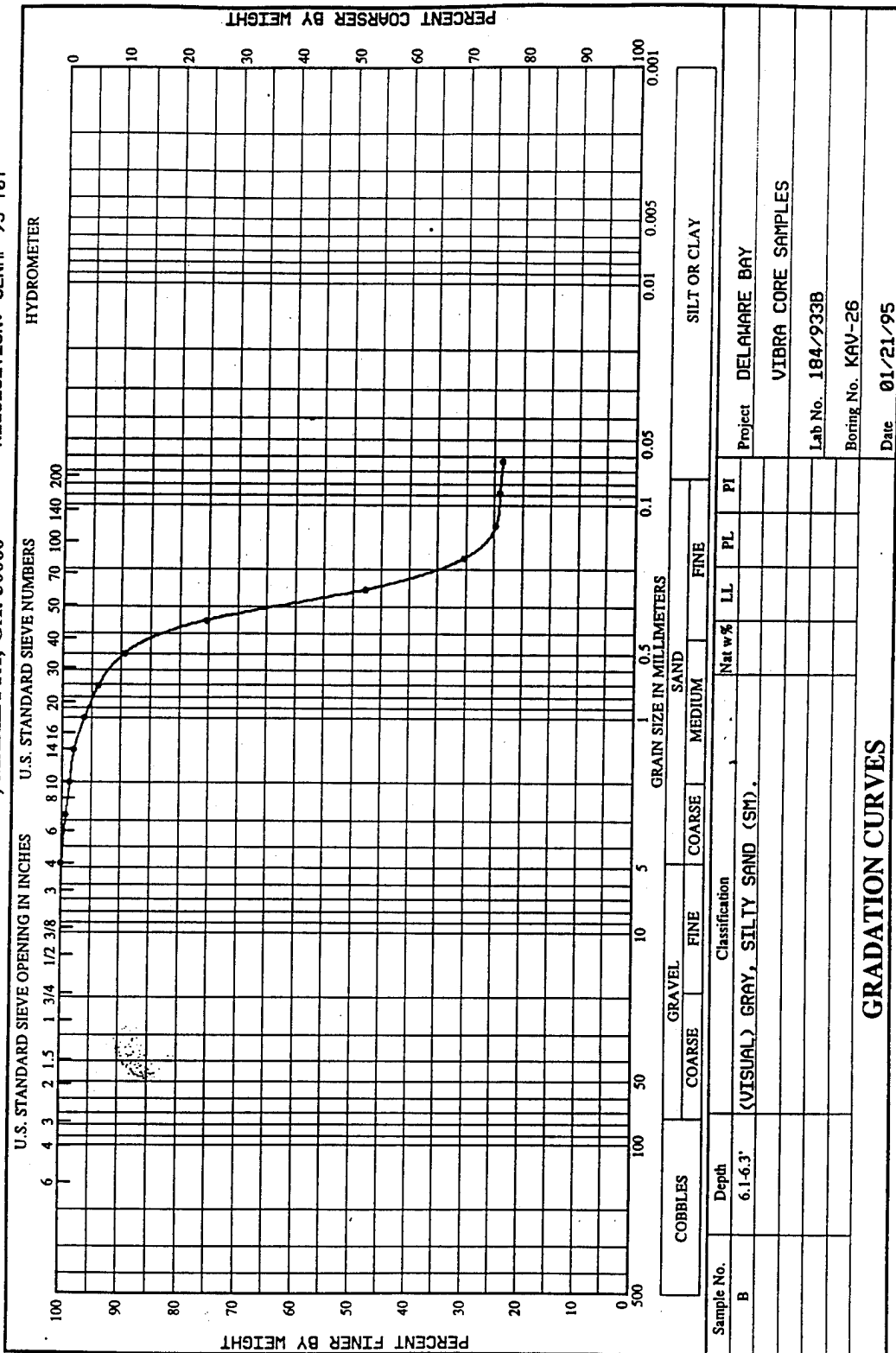


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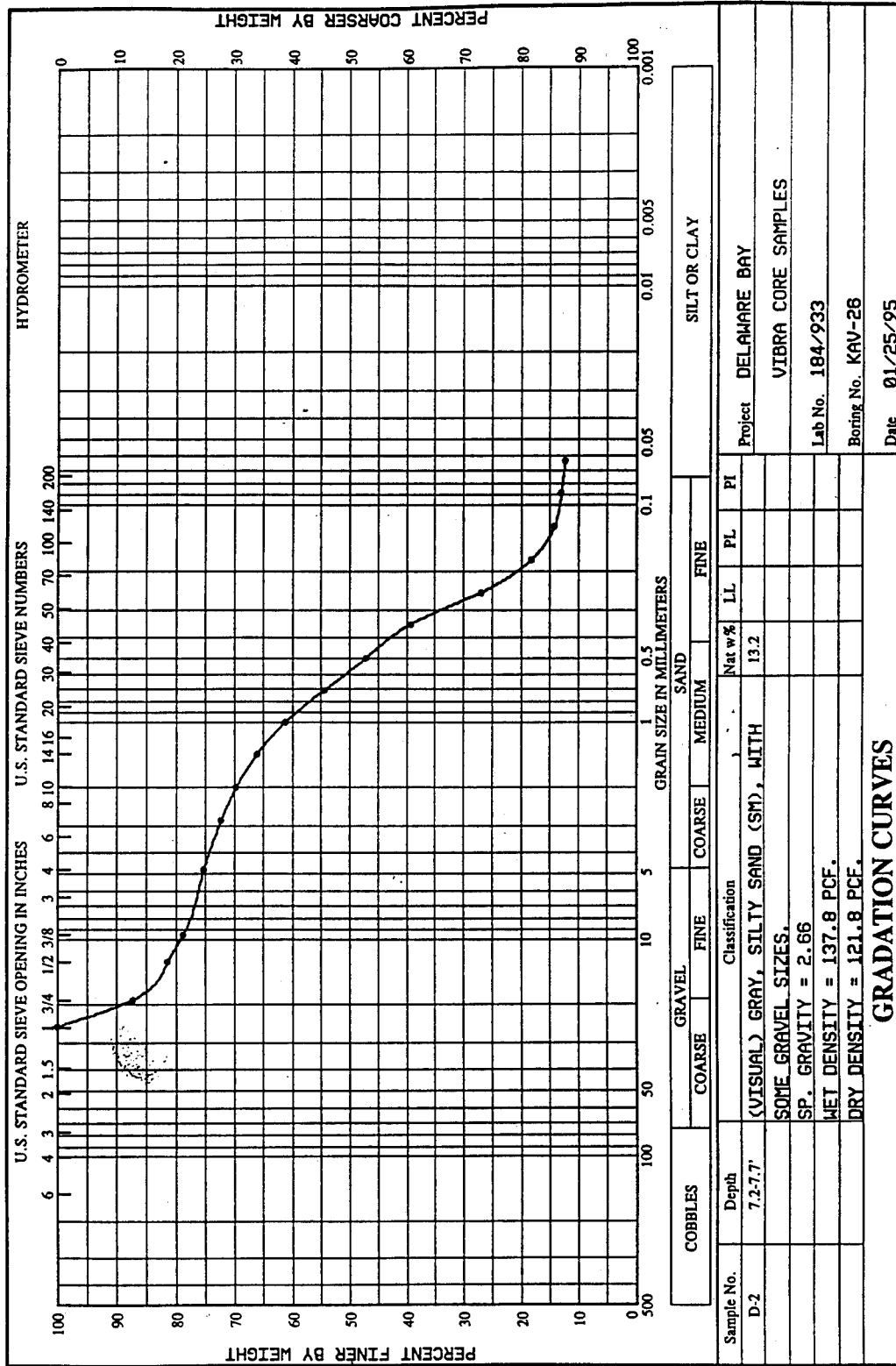


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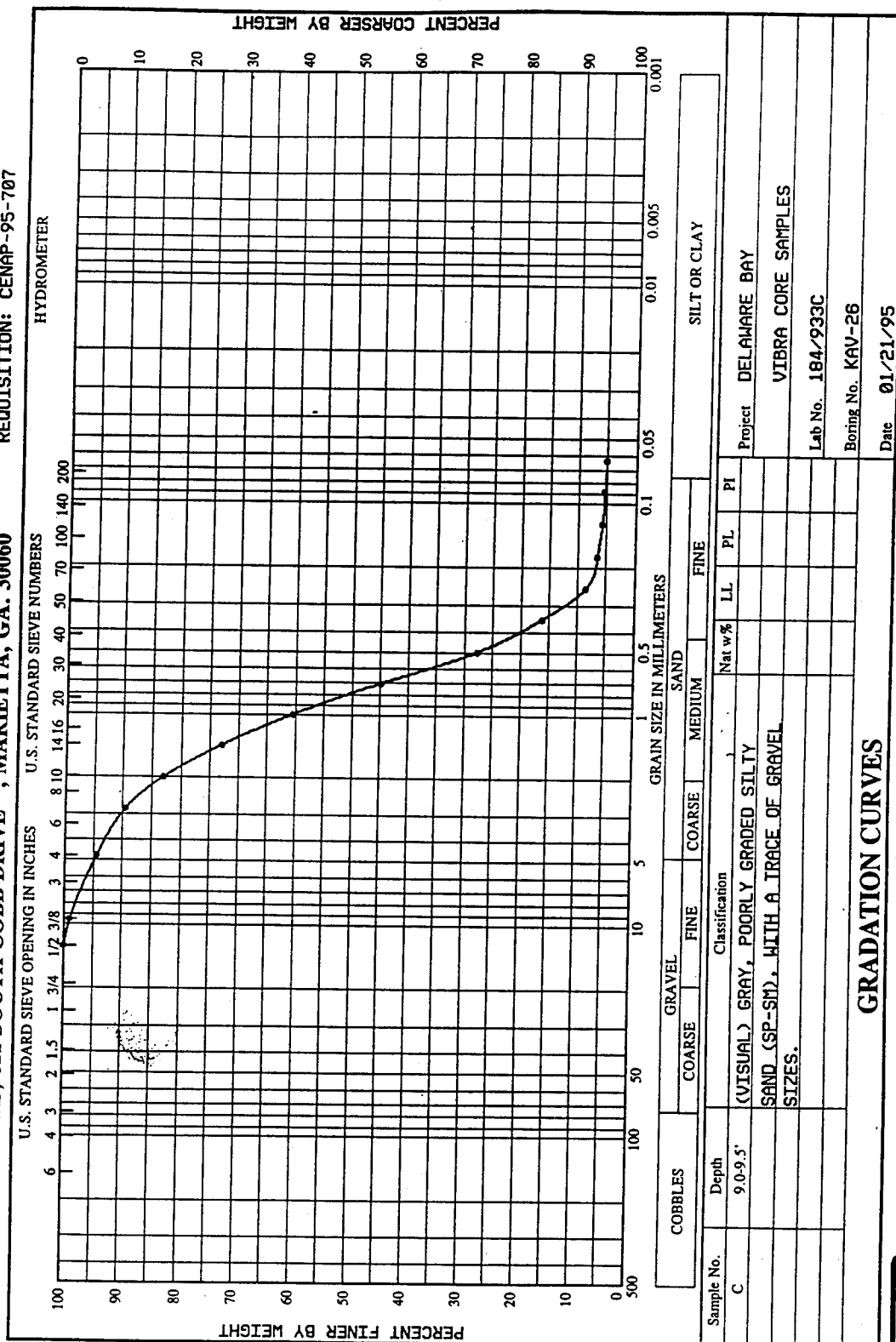


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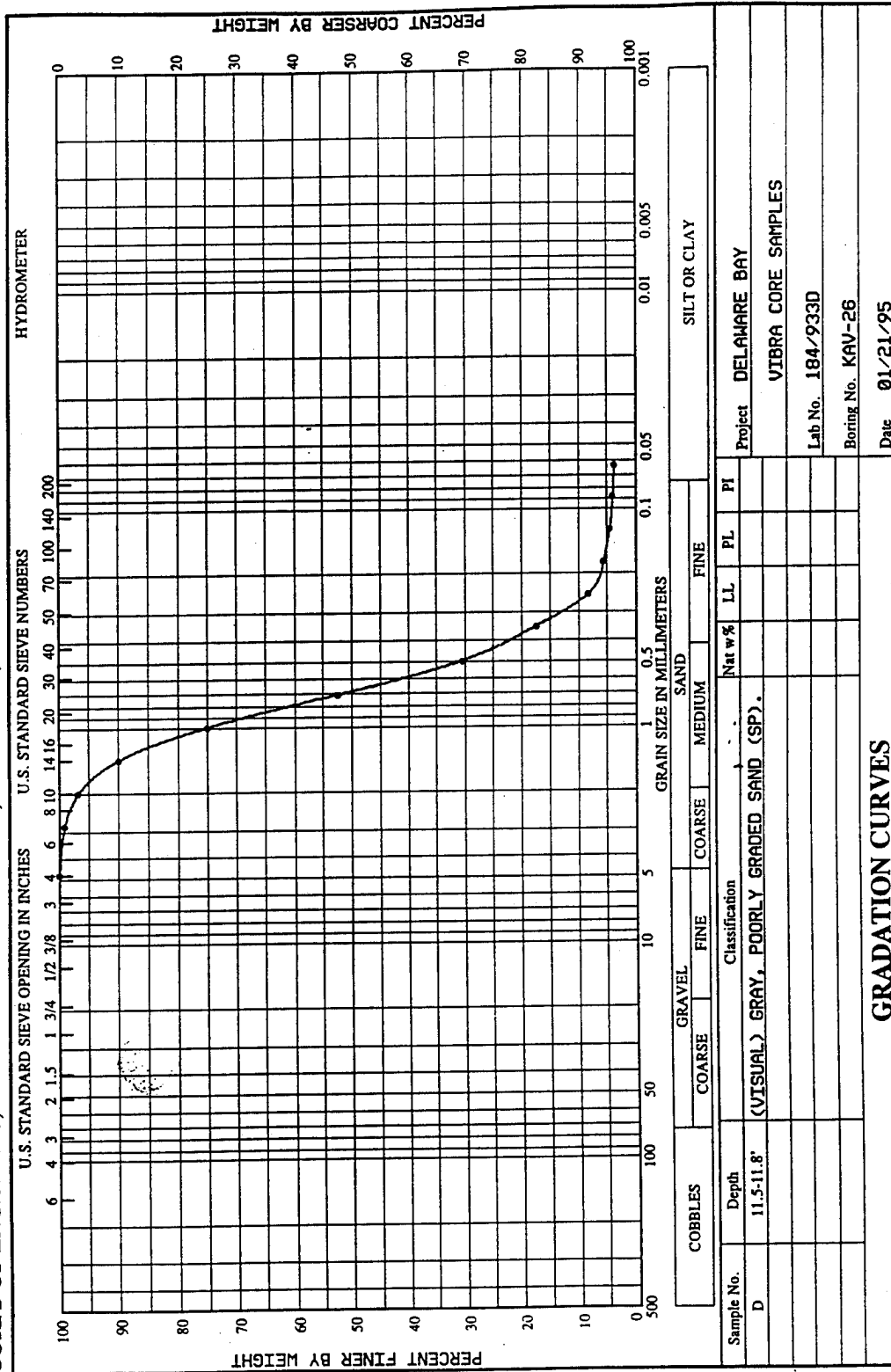
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WORK ORDER: 7476
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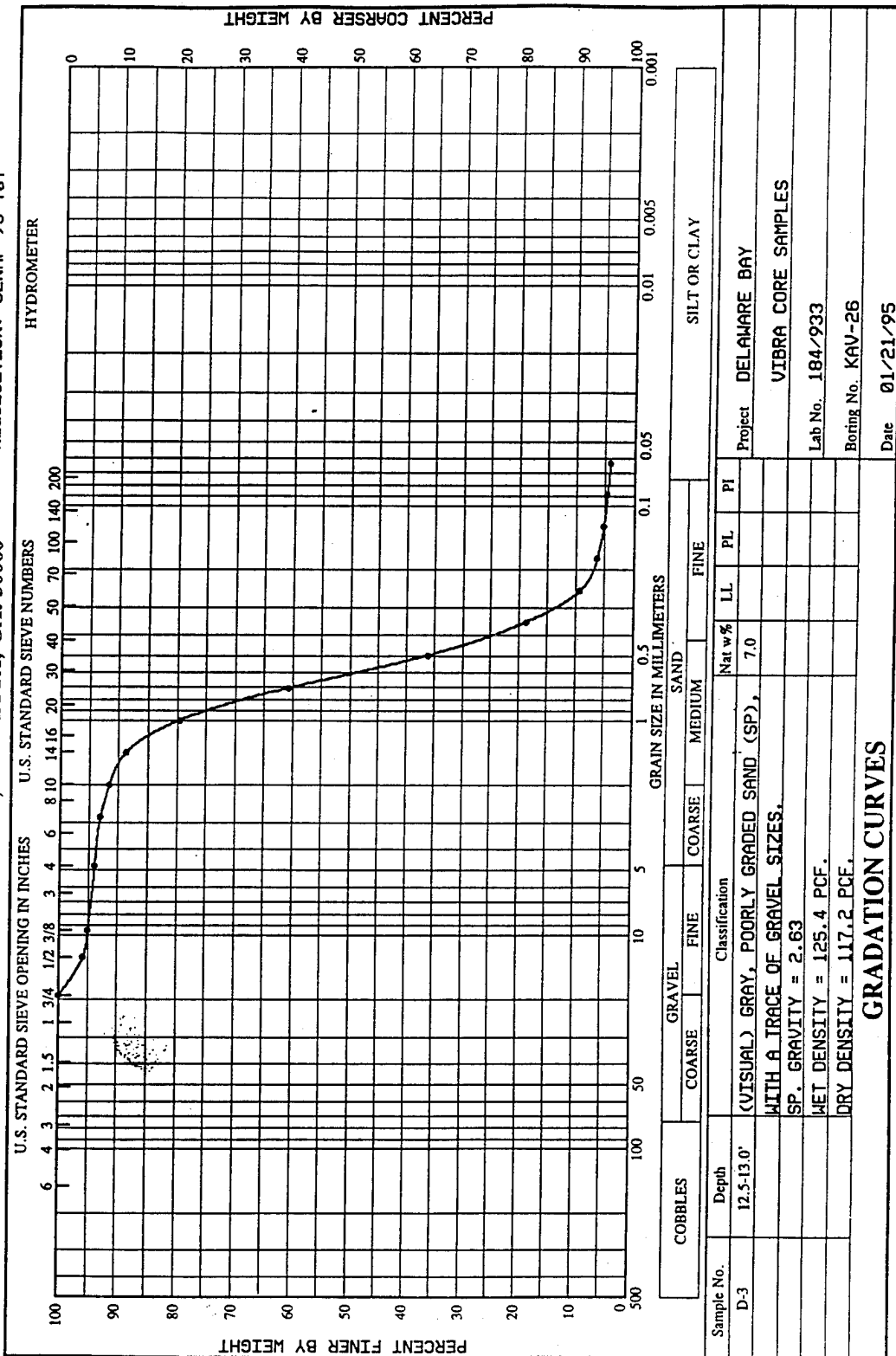


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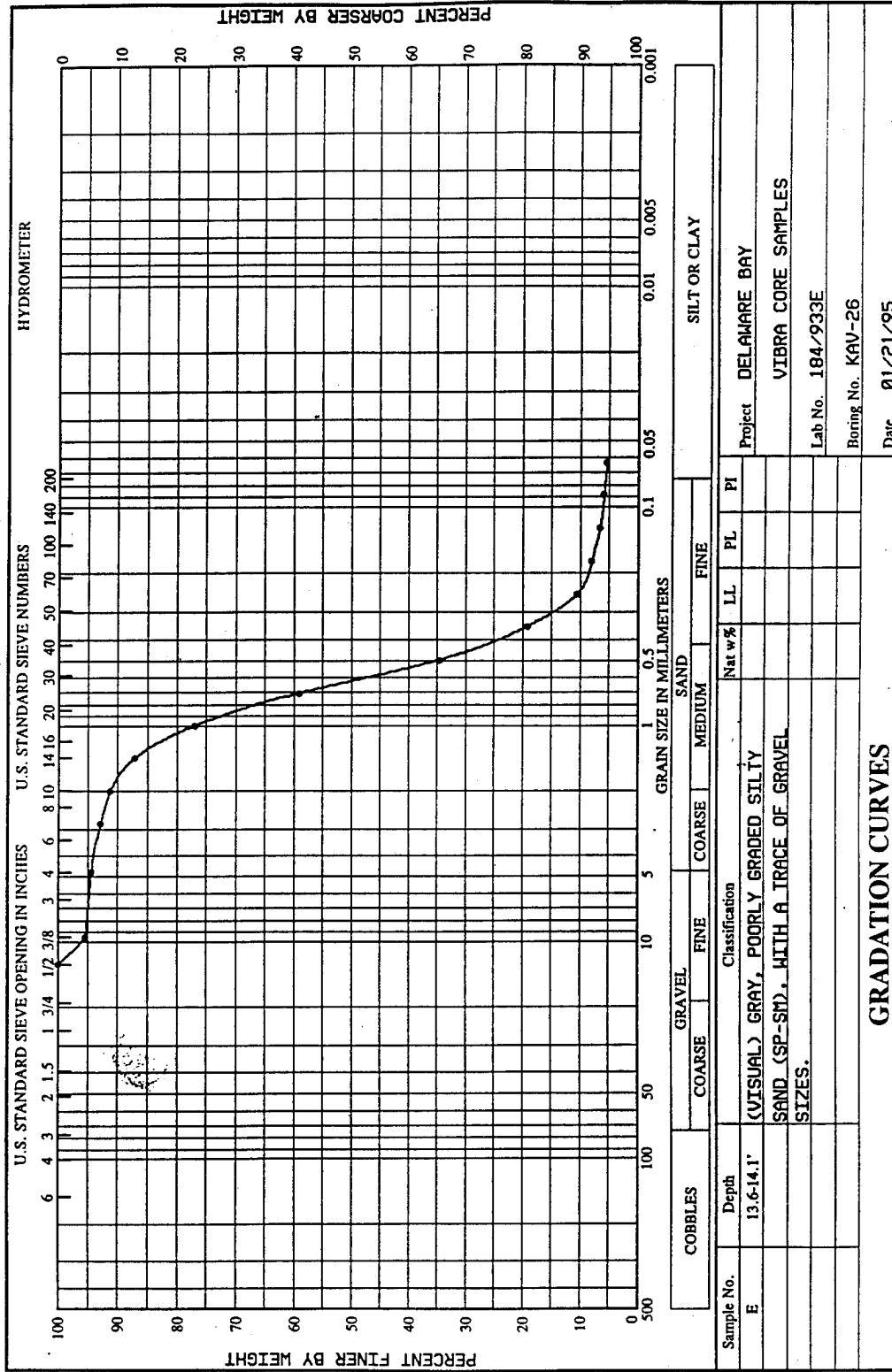


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REPORT DOCUMENTATION PAGE

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| 1. AGENCY USE ONLY (Leave blank) | | 2. REPORT DATE July 1996 | 3. REPORT TYPE AND DATES COVERED Report 1 of a series |
| 4. TITLE AND SUBTITLE Sediment Characterization and Beachfill Borrow Area Assessment of the Delaware Bay Study; Report 1, Identification of Sediment Types Offshore of the Broadkill Beach, Delaware, Area | | | 5. FUNDING NUMBERS |
| 6. AUTHOR(S) Donald K. Stauble, Richard G. McGee | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road Vicksburg, MS 39180-6199 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER Miscellaneous Paper CERC-96-6 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Engineer District, Philadelphia Wannamaker Building, 100 Penn Square East Philadelphia, PA 19107-3390 | | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER |
| 11. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. | | | |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. | | | 12b. DISTRIBUTION CODE |
| 13. ABSTRACT (Maximum 200 words) Erosion is occurring along the shoreline of Delaware Bay, comprising the east coast within the state of New Jersey and the west coast within the state of Delaware. This erosion has resulted in a need to investigate the shallow offshore areas of the bay adjacent to both the Delaware and New Jersey coasts for use as borrow areas for beachfill material. The area is relatively unexplored from a geotechnical standpoint and this investigation will provide acoustical subbottom profiling, vibracore locations, and interpretation of the sediment substrate of the study area. Seismic and sedimentological data from vibracore samples were interpreted, and this report characterizes the sediment of the Broadkill Beach portion on the west side of the bay of the Delaware Beach study. This report also suggests suitable borrow areas for beachfill use. | | | |
| 14. SUBJECT TERMS Beachfill borrow area assessment Broadkill Beach Delaware Bay | | | 15. NUMBER OF PAGES 126 |
| | | | 16. PRICE CODE |
| 17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED | 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |